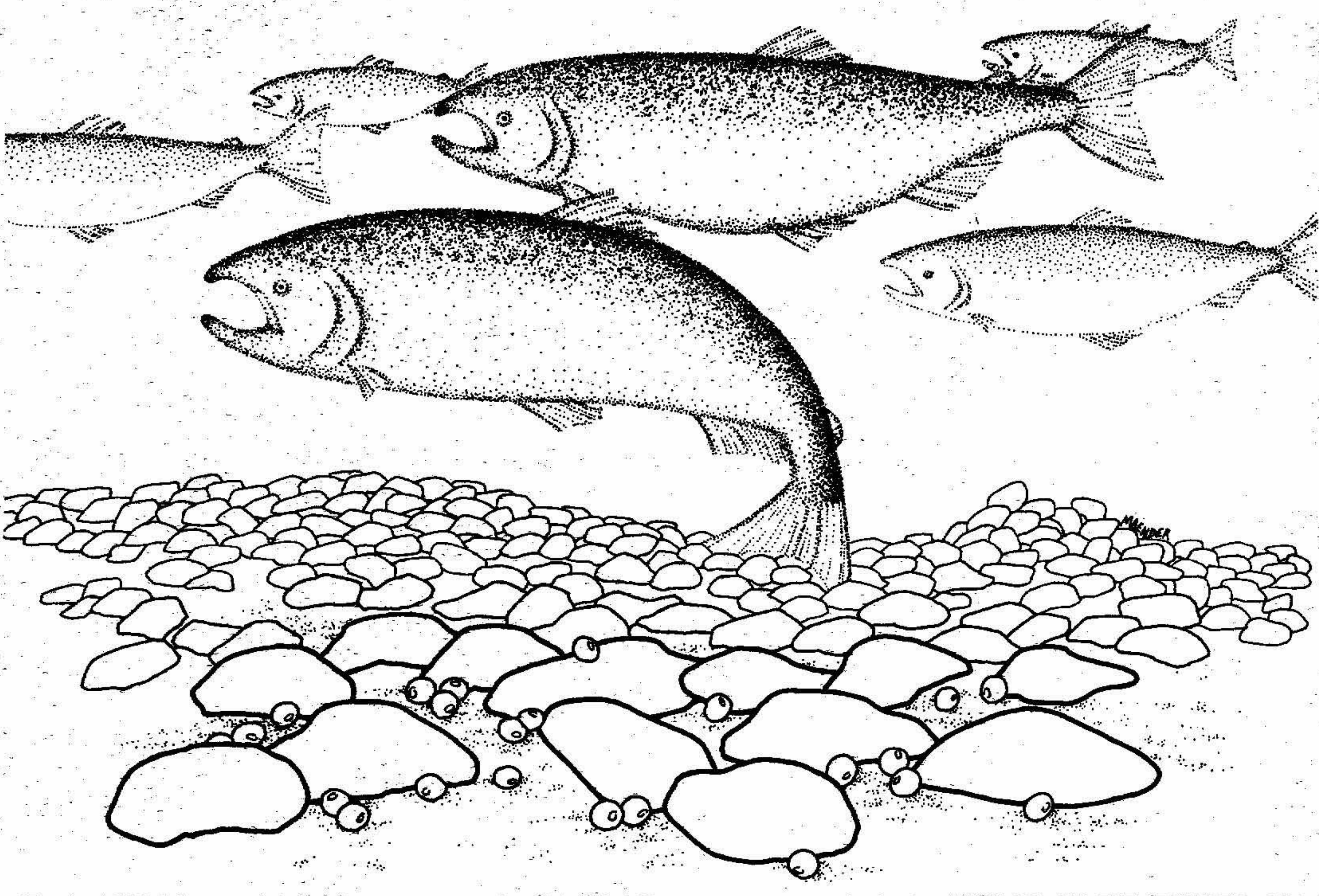
U.S. Fish and Wildlife Service
Fisheries Assistance Office
Olympia, Washington

# An Investigation Of The Limiting Factors To Lake Ozette Sockeye Salmon Production And A Plan For Their Restoration



# An Investigation Of The Limiting Factors To Lake Ozette Sockeye Salmon Production And A Plan For Their Restoration

by

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# PREFACE

The involvement of the United States Fish and Wildlife Service (FWS) with Lake Ozette began in 1924 when Kemmerich (1945), then District Supervisor, established a counting weir in the Ozette River. In 1924 (partial count) and 1925 he enumerated 3,251 and 6,343 sockeye, respectively. The purpose of the survey was to attempt broodstock capture for artificial propagation purposes, but attempts were unsuccessful due to poor design and location of holding facilities.

In the 1930s the FWS released Quilcene-reared sockeye fingerlings ranging from 2.5 to 7.6 cm into Lake Ozette. Kemmerich (1945) also reports that Quinault stock was planted in Ozette, but details of the Quinault plants are unavailable. The Quilcene-reared sockeye were from the Baker River stock.

In 1973, responding to Congressional Inquiry #FSF-1918, the FWS conducted limited spawning ground surveys around the lake (J. Meyer, personal communication, 1977). Local residents believed that windfalls along the Ozette River were impeding fish passage to the lake. The jams were removed in 1976.

At the request of the Makah Tribe in 1976, as part of a joint study between the Tribe, the United States Geological Survey (USGS), and the FWS, we began this study to determine the current status of Lake Ozette sockeye salmon.

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## ACKNOWLEDGMENTS

We thank Pete Ward, Ralph Butterfield, Jeff Hotowe, Steve Pendleton, Al Hartt and Steve Joner of the Makah Fisheries Office for field assistance; Dr. S. F. Jerry Cook, Sally Klotz, Charles Stephens, Debra Leslie, Michelle LaGory and Luann McVey of The Evergreen State College for life history investigations; Neil and Roxanne Hildebrand, James Wessler, Clyde Bugher, Rob Snyder and Don Olsen of Lake Ozette for observations and making available laboratory and field office facilities; the National Park Service and the Washington Departments of Fisheries and Game for their continuing cooperation; James Mullan, who encouraged our investigation, and numerous other FWS employees for data collection and statistical analysis; Dr. S. F. Jerry Cook, Dr. Ernie Brannon, Douglas Canning and Robert Ringo for reviewing the manuscript.

## INTRODUCTION

The harvest of sockeye from the Ozette watershed has declined dramatically since the late 1940s. However, the decline has been evident for other species as well as sockeye (Table 1). The decreases in the harvests of all species may partially have been caused by similar factors; however, other causes are probably species specific. For example, chinook and chum salmon production occurs in the mainstem Ozette River below the lake which is an area in pristine condition. The decline in harvest is, therefore, probably attributable to a lack of effort, as the last full-time Makah residents near the river mouth moved to Neah Bay in the late 1950s. Declines in the harvest of coho salmon can also be attributed to this lack of effort, compounded with a coastwide decline in river harvest directly attributable to increased prior interceptions in the international coastal troll and sport fisheries and the degradation of spawning grounds in the tributaries to Lake Ozette caused by poor logging practices and associated road-building activities. The effort on sockeye salmon, however, has remained near historic levels and prior off-shore interceptions are considered to be negligible. Therefore, we conjectured that the decline in production from a reported harvest of 17,600 sockeye in 1949* to the current total run size of less than 1,000 sockeye could be attributable to overharvest, habitat degradation, and introductions of competitory and predatory species.

The following study is an attempt to document the limiting factors and develop a plan for increasing sockeye production to historical levels. In this regard we performed the following sockeye investigations: adult enumeration; spawning ground surveys and evaluation of the spawning gravel; egg deposition to fry emergence; lacustrine residence; smolt condition and enumeration; disease surveys; and the potential of Lake Ozette for sockeye rehabilitation.

## DESCRIPTION OF STUDY AREA

Lake Ozette (Figure 1), the third largest natural lake in Washington State, has a surface area of 2,954 hectares and drains 128 square kilometers (Bortleson and Dion, 1979). The lake has a mean depth of 39.6 meters and a maximum depth of 98 meters. The lake remains ice-free during the winter and fluctuates 2.7 meters in depth during the year. The lake is used by local residents and the National Park Service (NPS) as a domestic water source.

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*Catch data from 1948-1972 is extremely unreliable and is presented here primarily to illustrate a general decline in harvest.

TABLE 1.--Numbers of salmon taken by Makah Indians from Ozette River near mouth, 1948-75[1]

| Year | Chinook | Chum | Coho | Sockeye | Totals |
|---|---|---|---|---|---|
| | Salmon species | | | | |
| 1948 | 491 | 1,063 | 1,991 | 3,850 | 7,395 |
| 1949 | 1,876 | 1,339 | 1,572 | 17,638 | 22,525 |
| 1950 | 1,629 | 1,226 | 2,407 | 14,556 | 19,818 |
| 1951 | 1,213 | 1,021 | 1,103 | 15,074 | 18,441 |
| 1952 | 396 | 682 | 3,697 | 3,047 | 7,822 |
| 1953 | 431 | 431 | 906 | 2,380 | 4,148 |
| 1954 | 823 | 907 | 862 | 2,110 | 4,702 |
| 1955 | 404 | 806 | 1,031 | 1,107 | 3,348 |
| 1956 | 241 | 0 | 1,149 | 1,396 | 2,786 |
| 1957 | 428 | 0 | 1,119 | 512 | 2,059 |
| 1958 | 147 | 0 | 721 | 395 | 1,263 |
| 1959 | 0 | 0 | 0 | 682 | 682 |
| 1960 | 0 | 0 | 0 | 1,851 | 1,851 |
| 1961 | 3 | 0 | 281 | 1,054 | 1,338 |
| 1962 | 0 | 0 | 385 | 1,645 | 2,030 |
| 1963 | 1 | 1 | 263 | 1,551 | 1,816 |
| 1964 | 1 | 0 | 350 | 448 | 799 |
| 1965 | 1 | 0 | 407 | 257 | 665 |
| 1966 | 0 | 0 | 504 | 405 | 909 |
| 1967 | 0 | 0 | 272 | 313 | 585 |
| 1968 | 0 | 0 | 385 | 468 | 853 |
| 1969 | 0 | 0 | 189 | 295 | 484 |
| 1970 | 1 | 0 | 296 | 432 | 729 |
| 1971 | 0 | 0 | 244 | 328 | 596 |
| 1972 | 0 | 0 | 325 | 346 | 671 |
| 1973 | 0 | 0 | 0 | 49 | 49 |
| 1974 | 0 | 0 | 0 | 0 | 0 |
| 1975 | 33 | 0 | 0 | 0 | 33 |
| 1977 | 0 | 0 | 0 | 84 | 81 |
| 1978 | 0 | 0 | 0 | 30[2] | 30 |
| 1979 | 0 | 0 | 0 | 30 | 30 |
| 1980 | 0 | 0 | 0 | 30 | 30 |

[1]Numbers of fish taken by set nets or drag seines, as reported to Washington Department of Fisheries by Makah Indians (Ward and others, 1976, p. 108).

[2]Makah Tribal Regulations limited the sockeye harvest to 30 fish for ceremonial purposes.

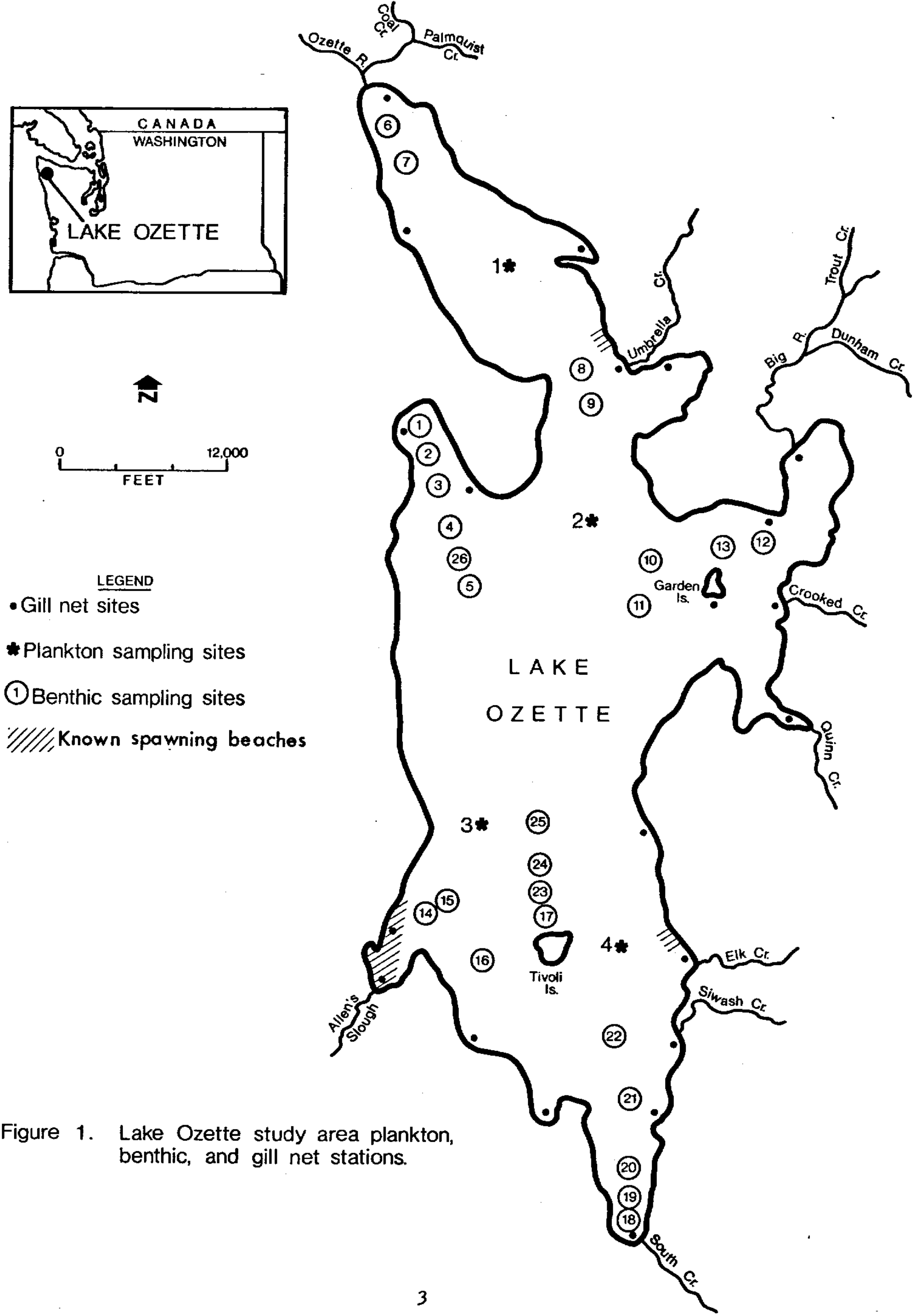


Figure 1. Lake Ozette study area plankton, benthic, and gill net stations.

The Ozette River, which drains the lake to the Pacific Ocean north of Cape Alava, drops only 9 meters in elevation from the outlet to the mouth, a distance of 7.8 kilometers. This gradient is uncharacteristic of coastal rivers in this area.

Geologically, the area west of Lake Ozette is underlain by glacial drift--gravel, sand, silt and clay--of Pleistocene age. The area east of Lake Ozette, with the exception of the headwaters of Umbrella Creek and Big River in the northeast, is underlain by terrace deposits--fluvial and glaciofluvial sand and gravel--of Pliocene and Pleistocene age. The headwater areas of Umbrella Creek and Big River are underlain by marine and nonmarine sandstone and siltstone of Tertiary age (Huntting et al., 1961).

Land use in the Ozette Basin consists primarily of timber harvesting and cedar salvage. The land north, east and south of the lake is owned primarily by the Crown-Zellerbach Corporation and ITT-Rayonier. The land west of the lake is within the confines of Olympic National Park; 60,000 tourists per year visit this western reach of the Park. The Makah Reservation at Ozette borders the lower reaches of the Ozette River. The Makah Tribe has historically utilized and depended upon the lake and river culturally and economically.

## METHODS

### Adult and Juvenile Sockeye Enumeration

The sampling gear for adult salmon consisted of a net, counting board, a light, and an observation platform (Figure 2). An arched concrete bridge constructed by the NPS across the Ozette River for access to various coastal trails provided a suitable observation platform. The bridge was 5 m above the river, which was 30 m wide at this point. Fish could also be counted from the river bank by adjusting the position of the counting board. The net was made of 5-cm stretched mesh on No. 30 seine twine of knotted nylon construction and set at a depth of 2 m. The guy-line was 2.54-cm polypropylene rope; the cork line was hollow-braid 1.25-cm polypropylene with 10.6-cm lead core and 1.25-cm chain. The counting board (4 x 1 m) was white formica bonded to an aluminum sheet; 70 kg of 7-cm-wide flat iron secured to the underside of the board provided a suitable anchor. It was illuminated by a single 12-V fluorescent tube 42 cm long, with a red cellophane shade, and the entire assembly was mounted on a wooden board. Power source for the light was 12-V marine battery which was charged at 80-h intervals. The light was hung from the guy-line above the counting board and the power supply wires run to the observation platform. A polypropylene guy-line 2.54 cm in diameter was secured to one of the bridge abutments and run at a $40^{0}$ angle downstream and across the river to a

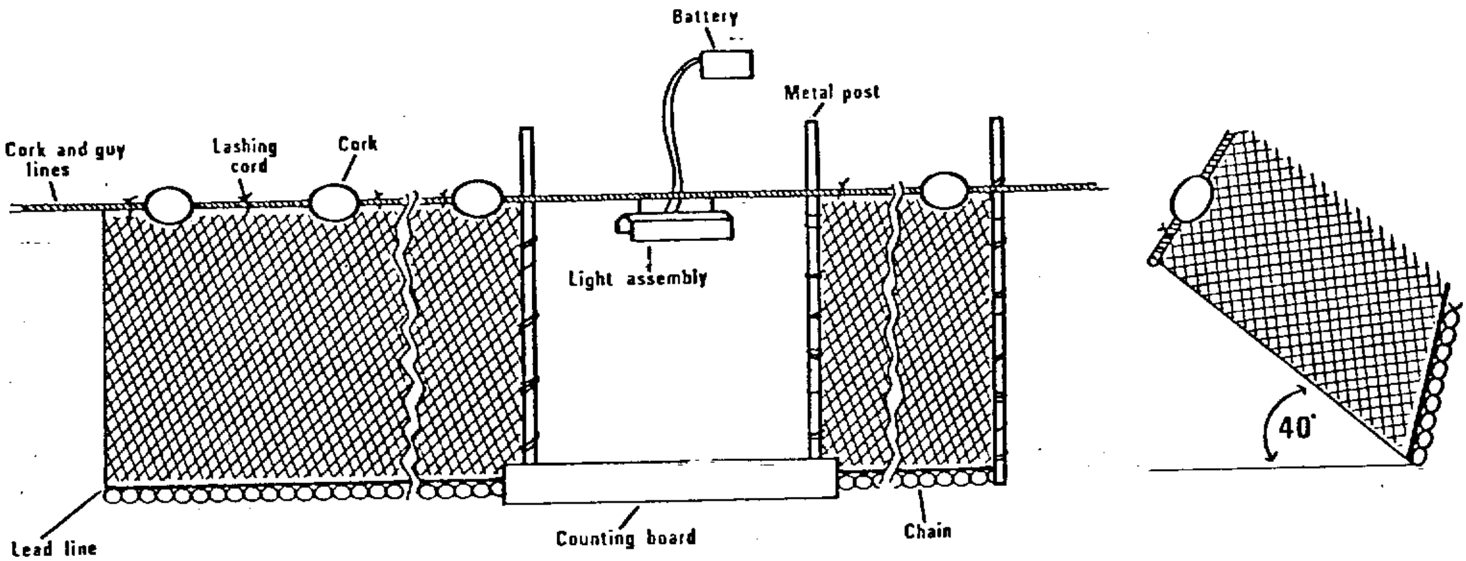


Figure 2a. Detail of net weir and counting board used in the Ozette River.

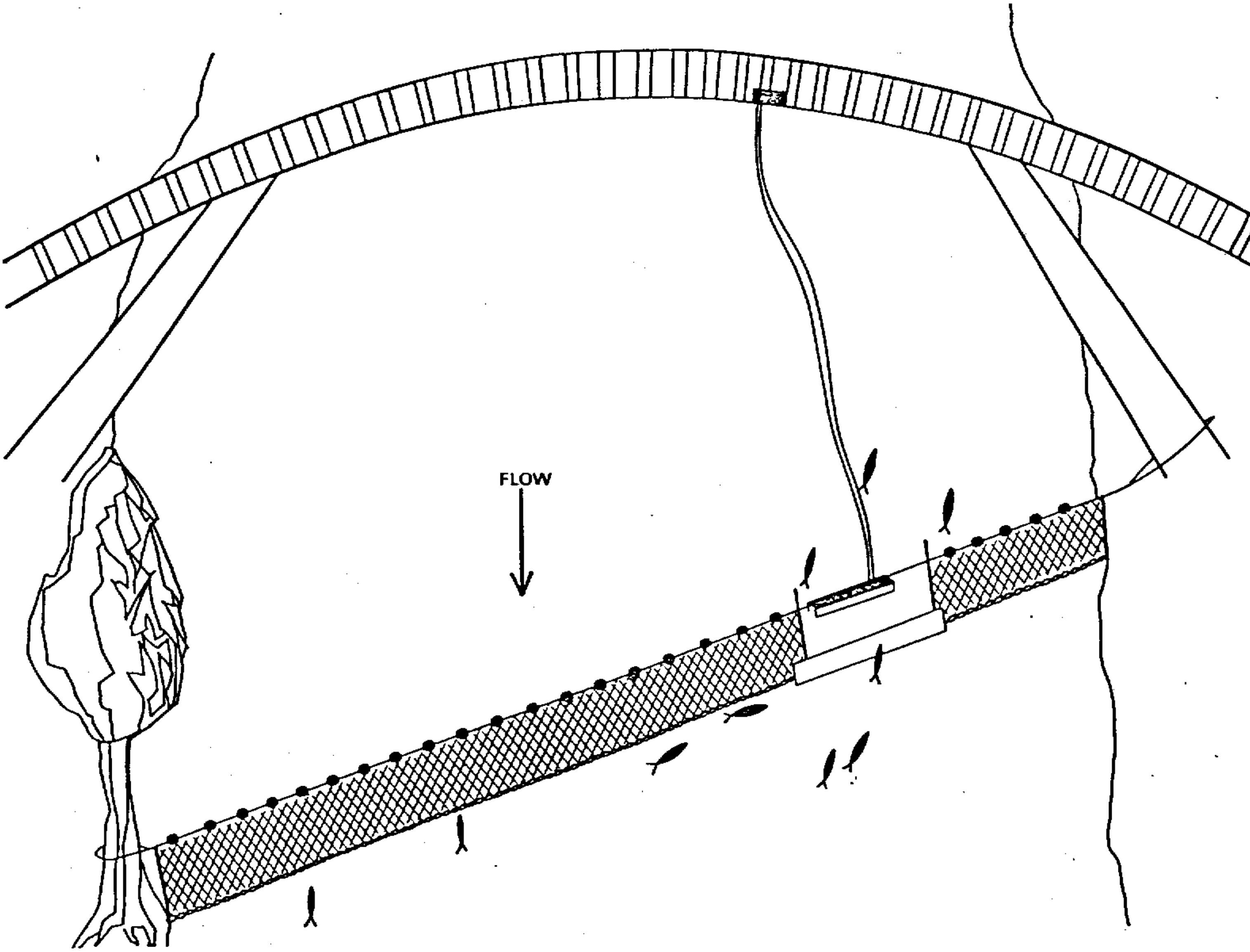


Figure 2b. Diagram of net weir and counting board used in the Ozette River (not to scale).

group of alders. This angle helped to lead the fish. The bottom contour at this cross section of the river consisted of a gravel bar in the center of the stream dropping to pools on either side, then gradually shallowing as the banks were approached. Stream depth ranged from 1.1 to 1.2 m and stream discharge was 300 $m^3/s$. The counting board was positioned in the upstream pool and the net was hung from the guy-line with parachute cord used as a lashing near each cork float. Metal fence posts supported the net at each corner of the counting board. Chain, weighing 2 kg/m, was laced to the lead line to ensure contact with the irregular stream bottom. A come-along was used on the downstream side of the supporting line to take up unnecessary slack.

Adult sockeye salmon migrate into Lake Ozette between dusk and dawn. Counters were rotated every 3-5 hours to prevent fatigue. Two counters were generally present for 1 hour to ensure quality control, as squawfish (*Ptychoceilus oregonensis*) and steelhead trout (*Salmo gairdneri*) were also present. The net was cleaned daily by lifting the lead line, passing leaves and branches, and brushing algae from the net.

The sampling apparatus for juvenile fish, modified after Healy (1970), consisted of a net frame, net, livebox, and rigging (Figure 3). The net frame (1.83 x 1.83 m) was made of 22-mm-square steel. Eye bolts for attaching the net, bridles and haul line were welded to the frame. The net was made of delta knotless nylon 1-cm stretched mesh. The net from the frame tapered to a 30.5-cm square opening at the cod end, where it was held open by 0.5-cm steel rod (30.5-cm square). A vinyl collar protected the net from abrasion where it was secured to the livebox by means of a metal slot. The net was equipped with a nylon zipper from frame to cod end to facilitate cleaning. The livebox was built of slotted aluminum plate heli-arced to aluminum angle iron and braced with aluminum flat bar. A hinged and latched door was installed in the top of the box. Pop-rivets were used on all bracing, hinges, handles, and latches. The box was buoyed underwater with closed cell foam poured in polyvinyl chloride pipe 15.3 cm in diameter to avoid disrupting the net taper. A metal slot at the front of the box secured the cod end of the net. A plywood baffle wedged into the box provided a resting area for the smolts.

The rigging consisted of 1.9-cm polypropylene line in an endless loop through pulleys secured to the alders on shore. The bridle lines from the net frame ran through the ratchet blocks and locked in place. These infinite adjustment blocks enables us to position the frame perpendicular to the river current. The frame was hauled vertically above the water by means of a propylene rope 1.2 cm in diameter run through a pulley secured to an overhanging alder. A block and tackle were used with a haul line. A polyethylene rope 1.2 cm in diameter was used to haul the livebox to shore. The sampling site was 0.4 km downstream from Lake Ozette, where the river was 3 m wide, with a substrate of cobbles and gravel. During April, May and June when the net was operated, water depths at the frame fluctuated from 1.1 to 1.8 m. Mean current velocity was 2 m/s, and flows fluctuated between 85 and 360 $m^3/s$.

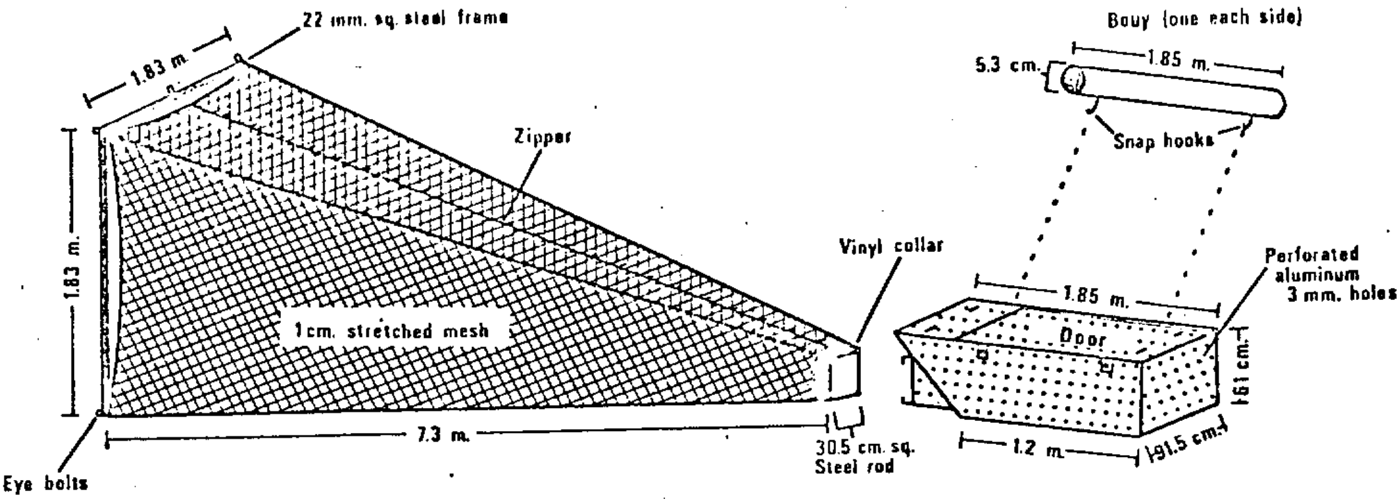


Figure 3a. Detail of fyke net and live box used to sample outmigrants in the Ozette system.

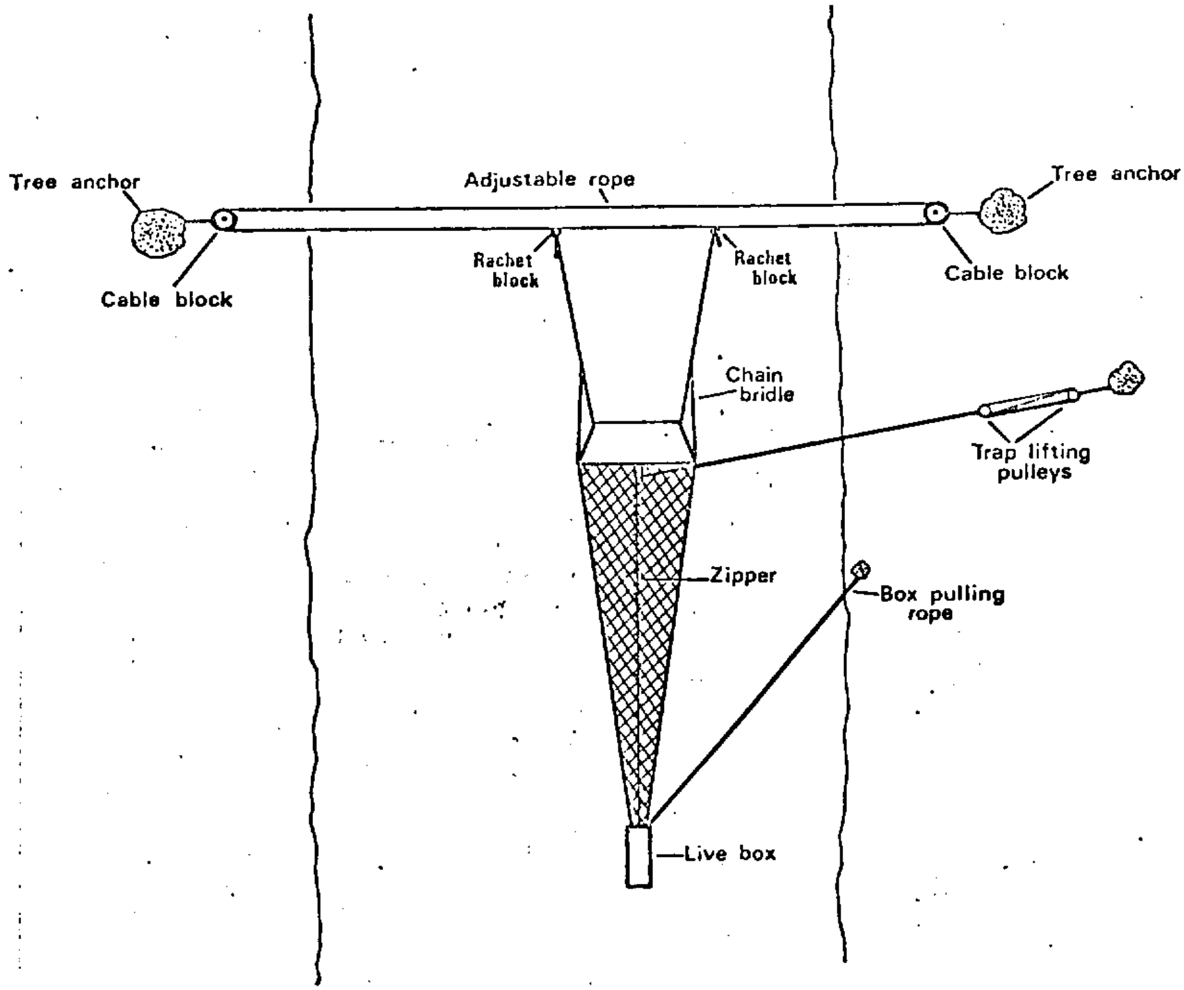


Figure 3b. Diagram of fyke net and apparatus used to sample outmigrants in the Ozette system (not to scale).

Throughout the experiment the net was fished in the swiftest portion of the river. At regular intervals the net frame was hauled 1 m above the water to prevent escapement, the livebox was hauled to shore, and the fish were dipped from the box. A hand-held 6-V lantern provided sufficient illumination for one person to conduct the operations through the night. The net was generally checked at 3-hour intervals, except when predatory fish appeared in the river in sufficient numbers to warrant hourly checks. The time required to haul the net, empty and record the catch, and return the net to a fishing position was 15 minutes.

We employed .32 cm (1/8") barmesh hardware cloth traps, 40 cm square, to determine the time of fry emergence from redds. Hydroacoustic surveys were conducted to determine fry and pre-smolt densities during lacustrine residence.

Predators and Competitors

Variable mesh experimental gill nets 44.2 m long were deployed monthly at random locations (Figure 1) throughout the lake from 1977 to 1979. Direct sets were also made over spawning areas in 1979-80 for virological sampling. The nets were set perpendicular to the shore and fished overnight. The 6 7.37-m-long mesh panels comprising the net varied from 1.5-inch stretch mesh to 4-inch in 0.5-inch intervals (3.81 cm to 10.16 cm in 1.27-cm intervals). Analysis of variance and covariance were utilized (L. Conquest, personal communication, 1980) to ascertain if seasonal and geographical fish distribution differences were significant.

Fork length and weight of each fish captured were recorded. Scales were removed from the left side of the fish from the second and third rows above the lateral line, directly posterior to the dorsal fin. When possible, sex was determined by either extrusion of milt or roe, or by dissection.

Length-weight relationships and coefficients of condition (K) were determined by computer. Coefficients of condition followed Carlander (1977) where $K=W\ 10^5/L^3$ (W = weight in grams; L = fork length in centimeters). Least squares regression was calculated for length and weight data from individual fish. Where necessary, the relationship was made linear by using a log transformation on both length and weight.

Fish were aged from scale annuli. Impressions of mounted scales were made on cellulose acetate cards, magnified on a microprojector from 20 - 60 times, and aged twice. If the readings differed, the scales were aged a third time. Regenerated scales were discarded. Fish were separated into year classes and lengths were back-calculated to obtain growth histories.

Food habits were determined by removing the entire digestive tract of approximately 10 percent of captured fish. These were preserved in 10-percent formalin. We used a dissecting microscope to sort and identify the contents of the digestive tracts. Prey items were keyed to major taxonomic groups and recorded as number of organisms per stomach and percentage composition.

### Disease Surveys

Fish captured for virological testing were processed in the following manner: ovarian fluid was expelled from ripe females and the fish returned live to the lake; kidneys, speens, and brains were procured from 65 spawned out or fresh dead fish. We sampled the kokanee population in the same manner. Samples were transported to the laboratory, processed, and analyzed according to the procedures outlined by the American Fisheries Society, Fish Health Section (1979).

### Plankton and Benthos

Standing crop estimates of zooplankton were obtained monthly in 1976 from February through November by USGS and again by FWS in 1979 from January through September. Vertical haul sampling methodology as described by Lagler (1952) was utilized to collect data from four locations within Lake Ozette (Figure 1) using a 153-micron mesh Wisconsin plankton net. At Station 1, samples were taken from 25 m, while at Stations 2, 3 and 4, collections were made from 27 m.

Identification and enumeration procedures followed principles outlined by Edmondson and Winberg (1971). All zooplankton samples were stained with rose bengal in order to preclude the possibility of including molted crustacean exoskeletons in density estimates.

During February and March 1979 we collected profundal fauna samples from 26 sites throughout the lake (Figure 1) because of reports by Rogers (1961) and Chapman and Quistorff (1938) that noted sockeye fry and smolts preying upon aquatic insects during initial lacustrine residence and final outmigration. Samples were obtained with a 232-$cm^2$ Ekman dredge. One grab constituted a sample, except at Station 15, where two grabs were combined because of inefficient dredge operation due to a hard substrate. Volumes of each grab ranged from approximately 16.7 $cm^3$ to 66.8 $cm^3$. Sampling was most effective in muddy/silty substrates. Additional procedures, such as sieving, preservation, and identification followed those outlined by Lind (1974).

## RESULTS AND DISCUSSION

### Adult Enumeration

The initial task that we addressed was to determine the total run size of the adult sockeye population returning to the lake via the Ozette River. In 1977 we established a counting weir in the river 0.2 km below the lake. We observed sockeye migrating into the lake between dusk and dawn from May to August (Figure 2). We conducted 24-hour counts on a bi-weekly basis during this period, but did not observe any sockeye migration during daylight hours. This nocturnal migratory pattern was also observed in the traditional tribal fishery at the mouth of the Ozette River, where catches of sockeye began on the evening high tide and stopped at dawn. Between June 18 and June 27, 1977, 84 sockeye were caught by the tribe and 46% of the fish were males. Only one of the sockeye taken in this fishery was a $3_2$* jack, as the 11.5-cm stretch mesh monofilament gill net was selective for $4_2$ adults. Adding catch (84 sockeye) to the escapement (920 sockeye), we determined the 1977 run size to be 1,004 fish.

The Makah fisheries staff issued regulations for the 1978, 1979 and 1980 run cycles which eliminated the tribal subsistence fishery while permitting a ceremonial harvest of 30 sockeye per year. Combining this harvest to the escapement, the run sizes for 1978, 1979 and 1980 were 920, 540, and 402 sockeye respectively. The escapements for 1977-1979 were based on counting every fish passing our weir between May 9 and August 6. We estimated the 1980 escapement based on the following:

$N = nq$ where:

$N$ = total run size estimate
$n$ = sample size
$p$ = average proportion of total run that passed the weir during a given period for 1977-79
$q = \frac{1}{p}$

In order to utilize the above, two assumptions were necessary: 1) $q$ was normally distributed, and 2) entry patterns were consistent between years.

$N$ = 255 (fish passing weir between June 5-June 24, 1980) x $\frac{1}{1.578}$ (proportion of total run represented between June 5-June 24 during 1977-79)

$N$ = 402. The run size for 1980 was 402 + 30 = 432 sockeye.

An explanation for the low returns of sockeye which was suggested by the tribe and the local citizenry was that log jams in the low river were impeding sockeye passage. Prior to takeover by the Olympic National Park, the river was kept free of jams. On July 6, 1978 and July 20, 1979 we floated the river and determined that at low flows of approximately 120 cm/second fish passage was not impeded. Further confirmation

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*Ages according to the Gilbert system. The large number indicates total age and the small number years in fresh water.

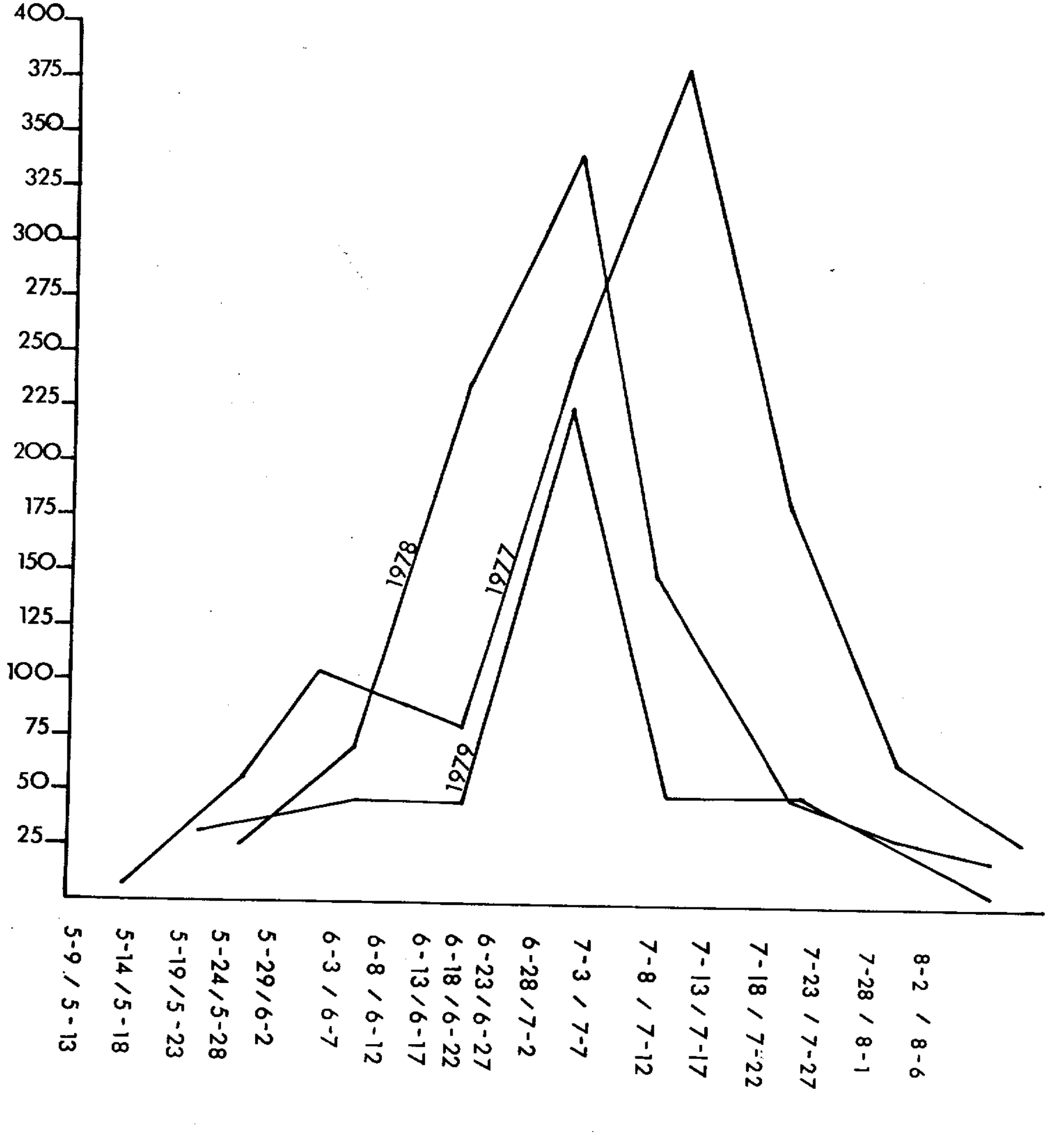



Fig.4 Timing and Abundance of the 1977– 1979 Lake Ozette Sockeye Escapement

was obtained at the weir site where we examined 12 incidental sockeye mortalities between 1977-80 and discovered that the external parasitic marine copepod *Argulus sp.* was attached to each sockeye mortality. Therefore, the fish appear to cover the 7.2-km distance from the ocean to the lake within 48 hours, as *Argulus sp.* is known to detach after 48 hours in fresh water (G. Wiedemeyer, personal communication, 1980).

We established length-weight relationships for the Lake Ozette sockeye from newly-emerged fry through mature adults. The equation of this relationship for 206 sockeye, sexes combined, captured in emergent traps, fyke nets, the tribal fishery and counting weir mortalities is:

$Log\ W = 1.83\ Log\ FL - 1.68.$ The $r^2$ is .96 (Figure 5).

The ages of 111 returning adult sockeye sampled in the tribal fishery and at the counting weir between 1977-79 were determined by examining scales. Age $3_2$ sockeye had an average length and weight of 40.7 cm and 0.91 kg, while $4_2$ fish averaged 56.4 cm and 2.2 kg. The equation of the length-weight relationship for returning adult sockeye is:

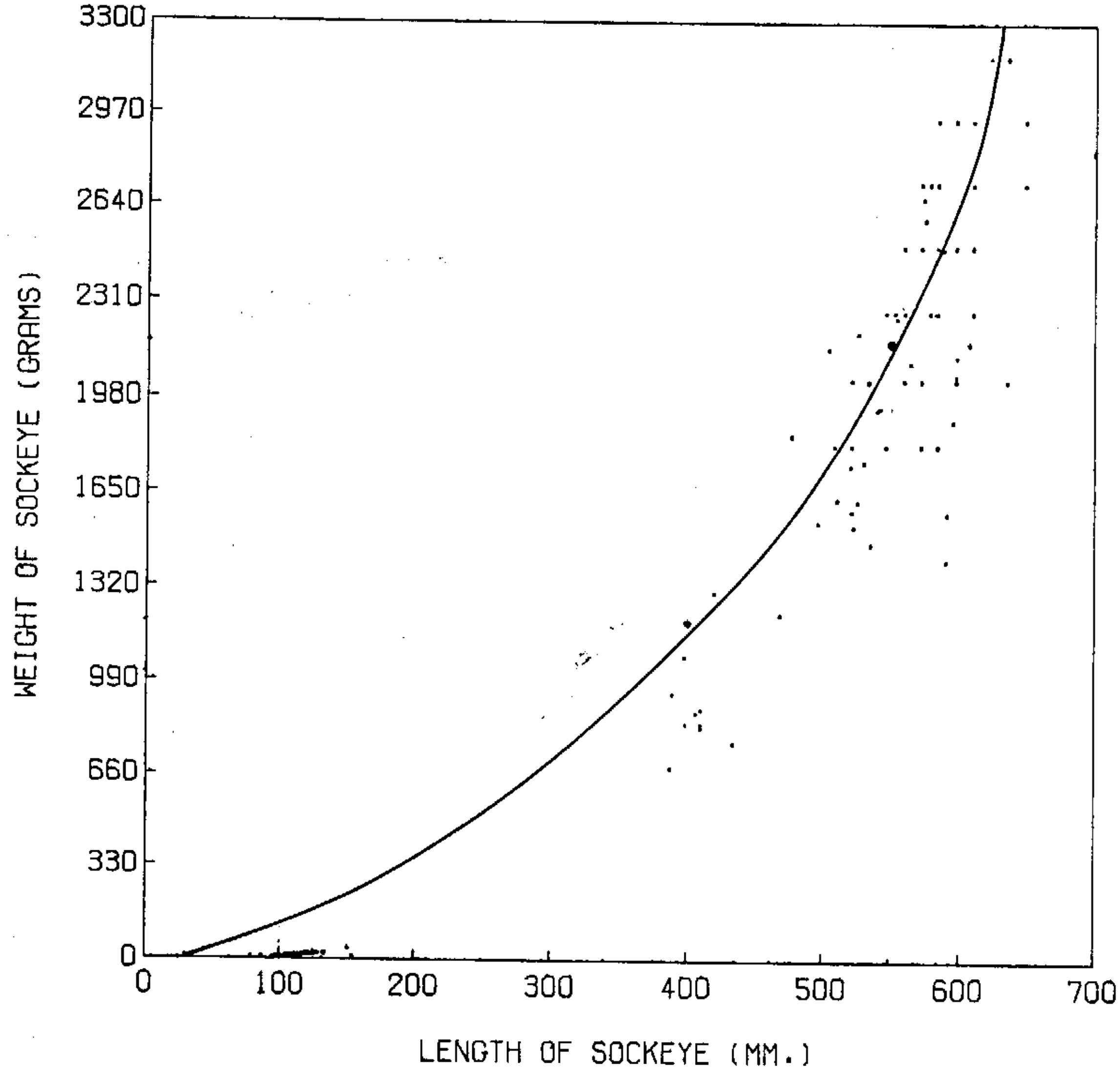
$Y = -2309.06 + 8.05X$ (Figure 6).

## Spawning Ground Characteristics

Foerster, in 1925, observed that sockeye salmon selected spawning areas associated with lakes in the following order of importance: lake tributaries; lakeshore in areas of upwelling springs; and the upper reaches of the outlet river. This pattern reflects observations along the Pacific coast from Kamchatka, Russia to the Columbia River, Washington (Foerster, 1968). Sockeye may utilize one or more of the above areas for spawning, but spawning area selection appears to be genetically inherent within sub-populations of the total sockeye spawners (Brannon, 1972). Brannon observed that tributary-spawning sockeye progeny will not select the outlet river for spawning, nor will lakeshore spawners utilize the tributary streams.

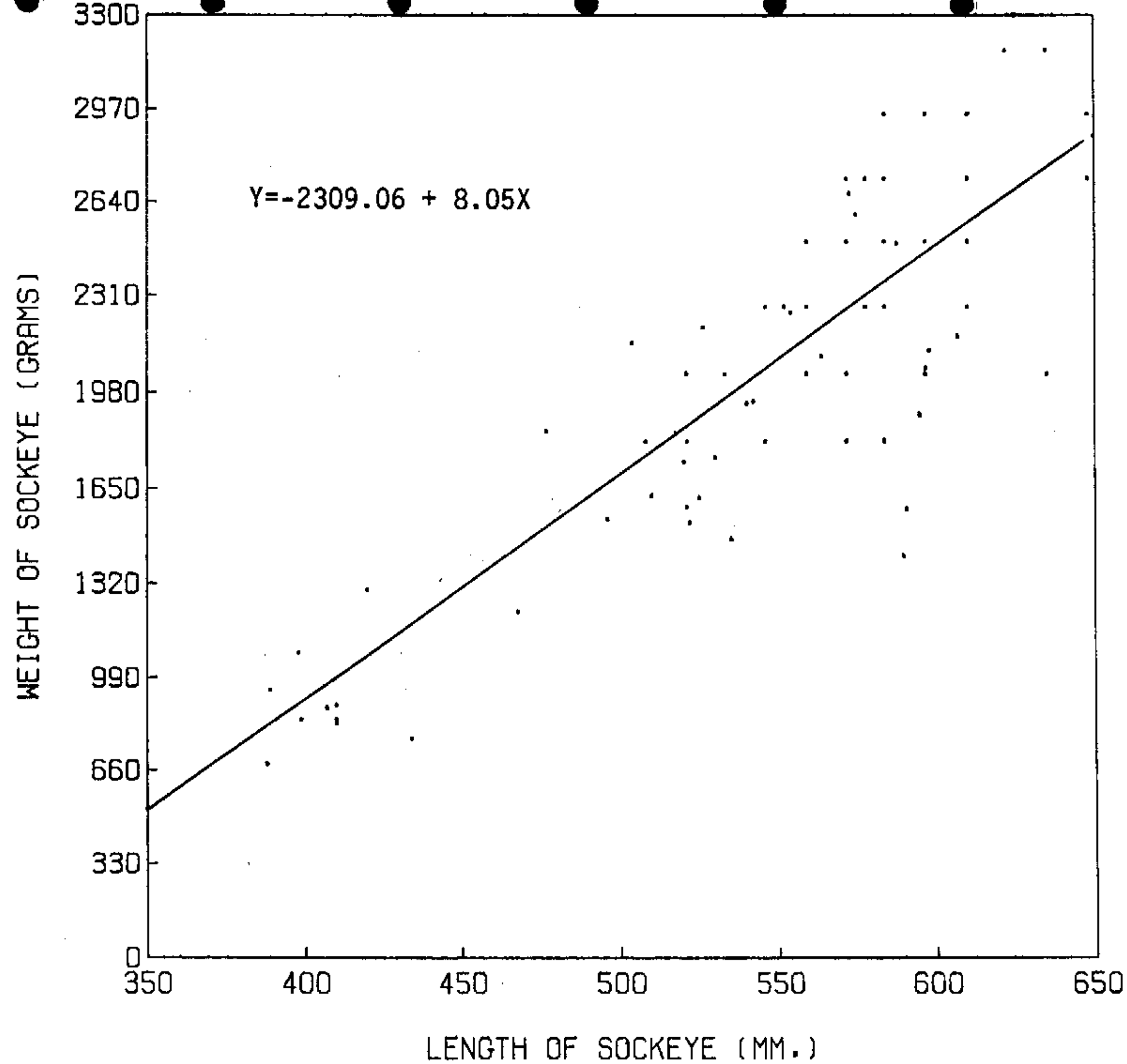
Spawning ground surveys were conducted from October through April for the 1977, 1978 and 1979 runs. The Washington Department of Fisheries (WDF) (W. Wood, personal communication, 1977) estimated salmon spawning potential for various Ozette tributaries. Their estimates (Table 2) indicated that suitable spawning grounds were available for 23,000 ± 6,500 sockeye in Big River and Umbrella Creek. We also found suitable tributary spawning conditions in Crooked Creek, Siwash Creek, and Lost Net Creek. Spawning potential for these three creeks is 2,000 ± 560 redds. These estimates were based on the existence of suitable spawning gravel for sockeye females at a rate of 3 square meters/female at optimum flows (Swift 1977).

Although sockeye have historically utilized Lake Ozette tributaries (P. Ward, J. Ayerst, E. Person, personal communication, 1978), foot surveys of these watersheds yielded no observable sockeye spawners




LENGTH VERSUS WEIGHT 206 VALUES

Figure 5.
1977-79 ADULT AND JUVENILE SOCKEYE, LAKE OZETTE




LENGTH VERSUS WEIGHT 111 VALUES

Figure 6,
1977-79 ADULT SOCKEYE, LAKE OZETTE

TABLE 2.--Estimated salmon spawning potential of Big River, Umbrella Creek, and other Ozette tributaries.

| Potential Capacity | Big River | Umbrella Creek | Others |
|---|---|---|---|
| River mile use, by sockeye1/ | 3.0 - 9.0 | 0.0 - 4.0 | 3.74/ |
| Area of spawning gravel at preferred flow, square yards2/ | 39,000 ± 11,000 | 31,000 ± 8,300 | 6,000 ± 1,700 |
| Area of spawning gravel as determined by Wash. Dept. of Fisheries, square yards1/ | 39,000 | 30,000 | |
| Number of redd sites at preferred flow3/ | 13,000 ± 3,700 | 10,000 ± 2,800 | 2,000 ± 560 |

1/ From Bill Wood, Washington Department of Fisheries, written communication, January 12, 1977.

2/ Based on unit spawnable area equations by Swift (1977).

3/ Assumes 3.0 wquare yards per sockeye redd and 100 percent potential area utilized (without overlap) by sockeye.

4/ USFWS Surveys 1977-79, Crooked Creek, Siwash Creek, and Lost Net Creek.

or carcasses, although we did encounter coho salmon and kokanee. A record of all surveys is presented in the Appendix.

Lakeshore surveys were conducted by boat during this same period. The tannic quality of the water limited observations to a depth of 3 m. Lakeshore-spawning sockeye were observed on the east shore north of Elk Creek; on the west shore from a point west of Tivoli Island to Allen's Bay; and north of the mouth of Umbrella Creek (Figure 1).

Elk Creek beach spawners were first observed on November 20, 1978 (Figure 7). These fish were concentrated in an area 25 m long from a depth of 0.3 m to an observed depth of 2.8 m. The largest number of spawners observed at any time was 60 fish in mid-December, 1978. While individual redds could be identified with a concentration of 30 fish, the presence of 60 obscured these distinctions. This suggests that competition for the spawning area over the upwelling spring was intense and could have led to the digging up of already buried eggs. Marginal nearshore areas were also utilized, as we observed the dessication of two redds prior to fry emergence. Spawning activity, including redd protection, could not be detected after mid-March.

Spawning sockeye were observed along the west shore of the lake from mid-December 1978 to April 1979. One hundred fifty spawners were observed in late January. The fish were fairly evenly spaced along this shore at a depth of 1-3 m. We did not observe any dessication of the redds prior to fry emergence.

Thirty spawners were observed utiliizing the beach area north of the mouth of Umbrella Creek on January 20, 1979 (Bugher, personal communication, 1979). A gravid male sockeye was recovered in March 1978 at this location. There was indirect evidence of spawning activity in Boot Bay, near Quinn Creek, as several ripe sockeye were captured in a gill net set during January 1979. The fact that these beach-spawning fish arrive on the spawning grounds at different times (Figure 7) indicates that they may be discreet sub-populations of the total stock (E. Brannon, personal communication, 1980). These sub-populations may have diverted from a common stock or are the result of plants from Baker Lake and Lake Quinault stocks.

## Fecundity

While the production of sockeye salmon in Lake Ozette depends primarily on the number of spawning females available, the number of eggs/female is also of consequence. Semko (1954), in comparing the fecundity of the different species of salmon, states:

> The fecundity is higher for those species of Pacific salmon, the young of which spend a longer period of time in fresh water prior to seaward migration ... in our opinion this reflects more severe conditions for survival of the young salmon in fresh water than in the sea.

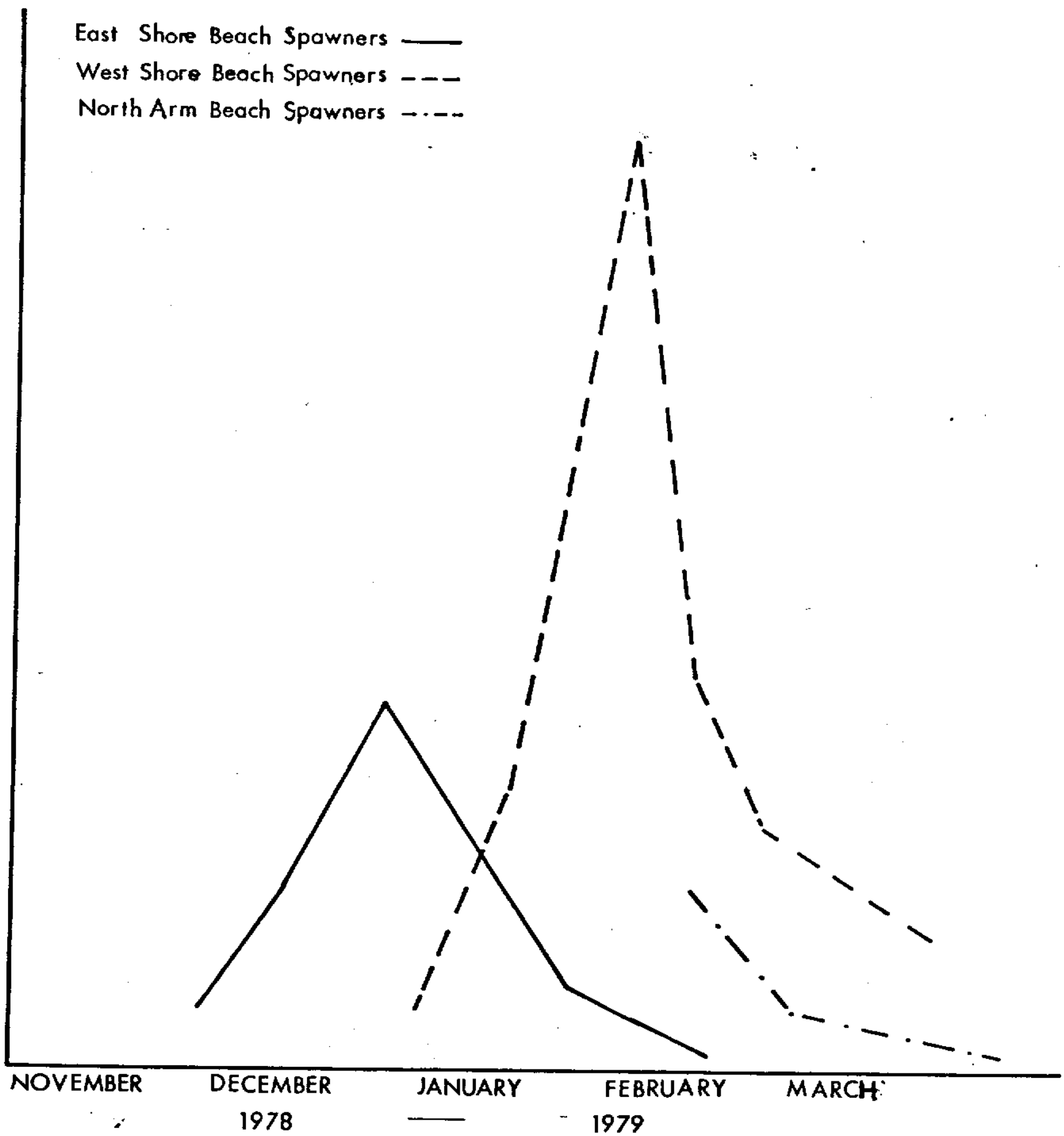



Fig. 7.. Timing and Abundance of Lakeshore Spawning Sockeye

We compared the fecundity of Lake Ozette beach spawning sockeye with ten other sockeye-producing systems in order to determine if there was anything biologically unique about the Ozette stock (Table 3), i.e., is fecundity a limiting factor to production? An analysis of fork length to fecundity reveals that Lake Ozette sockeye are "normal" with regard to egg production. The fecundity to fork length regression lines of four sockeye populations is illustrated in Figure 8. Not only do these lines differ between areas, but they also vary between years. The variation between years for Cultus and Babine lakes could be attributed to sampling error (only one year's data available for Pick Creek, Alaska and Lake Ozette, Washington). The variation between areas, however, reveals an inherited characteristic that is probably attributable to environmental parameters (Thompson 1959).

Rate of Egg Development

The rate at which sockeye eggs develop and hatch is dependent upon the temperature of the water in which the eggs are incubated. Foerster (1968) examined the rate of development from 10 hatchery incubation facilities (Table 4) and calculated the mean number of sockeye degree day units as 1069F. (593 C.).

We observed a pair of sockeye spawning on the east shore of the lake on January 4, 1979. We placed a thermograph on this redd upon completion of spawning. A hardware cloth trap was placed over the redd and the first emergent fry was observed on April 17. Smirnov (1958) reports that sockeye have a short alevin period and that fry emerge three to five weeks after hatching. Assuming that the alevin stage is similar at Lake Ozette, we calculated the period of incubation to be from 68-82 days, and the degree day units as 988-1215. This is comparable to other sockeye systems and does not appear to be limiting to production.

We used a hydraulic sampler to obtain eyed eggs from a portion of a single redd on the east shore on February 20, 1980 for subsequent hatching and viral analysis. We obtained 404 eyed eggs and 458 dead eggs from this effort. This 47% live-to-dead ratio is comparable to natural production in other sockeye systems (Brannon, Personal Communication, 1980).

Disease Surveys

Epizootics of infectious hematopoietic necrosis (IHN) have occurred in most sockeye populations associated with cultural operations (Watson et al. 1954). Surveys of natural populations in Alaskan waters (Grischkowsky and Amend 1975) found IHN virus in all locations tested. Surveys of British Columbian and Washington waters (Amend and Wood 1972; D. Mulcahey, personal communication, 1980) detected IHN at various levels in all stocks examined. If rehabilitation efforts at Lake Ozette will require intensive cultural activities, or the importation of stocks, it would be necessary to confirm the presence or absence of this virus. IHN virus was not detected in any of the 65 kidney and spleen and 100 ovarian fluid samples from Ozette adults taken in 1979-80 (R. Brunson, personal communication, 1980).

TABLE 3--Fecundity of sockeye salmon in relation to size, as reported for various areas.

| Area | Year | Mean length (cm) | Mean egg content | Authority |
|---|---|---|---|---|
| Babine Lake[a] | 1946 | 60.9 | 3281 | Withler (1950, p. 17) |
| | 1947 | 59.1 | 3187 | |
| | 1949 | 59.7 | 3353 | |
| Lakelse Lake[a] | 1939 | 59.6 | 3888 | Aro and Broadhead (1950, p. 18) |
| | 1948 | 59.0 | 3860 | |
| | 1949 | 58.1 | 3699 | |
| Pick Creek, Wood River[b] | 1948 | 55.3 | 3968 | Mathisen (MS, 1955) |
| | 1950 | 53.8 | 4096 | |
| | 1951 | 52.0 | 3944 | |
| | 1952 | 51.7 | 3952 | |
| Kurile Lake, Kamchatka[c] | | | | |
| River spawners | 1929 | (57.6) | 3790 | Krokhin and Krogius (1937b, p. 96) |
| River spawners | 1930 | (56.1) | 3895 | |
| Stream spawners | 1932 | (58.9) | 3600[d] | |
| Lake spawners | 1932 | (59.0) | 4585 | |
| Lake Dalnee, Kamchatka[e] | – | (51.2– 54.0) | 2500– 2600 | Krogius and Krokhin (1948, p. 4) |
| Lake Blizhnee, Kamchatka[e] | – | (49.0– 51.0) | 2000– 2400 | Krogius and Krokhin (1948, p. 4) |
| Port John, B.C. | 1949(18)[f] | 51.3 | 2425 | Biological Station, Nanaimo, B.C. |
| | 1950(9) | 50.8 | 2157 | |
| | 1951(5) | 54.3 | 2632 | |
| | 1952(7) | 52.5 | 2436 | |
| | 1953(8) | 54.8 | 2808 | |
| | 1954(9) | 55.2 | 2711 | |
| | 1955(15) | 52.0 | 2577 | |
| | 1956(15) | 52.3 | 2694 | |
| | 1957(5) | 54.2 | 3101 | |
| | 1958(14) | 53.1 | 2998 | |
| Karluk Lake, Alaska | 1938– 41($5_3$)[g] | 58.8 | 3306 | Rounsefell (1958a, p. 466) |
| | 1938– 41($6_3$) | 60.6 | 3018 | |
| | 1938– 40– 41($6_1$) | 59.7 | 3238 | |
| | 1939, 1941($7_4$) | 59.7 | 2968 | |
| Cultus Lake, B.C. | 1932 | 58.5 | 4310 | Foerster and Pritchard (1941, p. 53) |
| | 1933 | 56.5 | 3796 | |
| | 1934 | 59.0 | 4282 | |
| | 1935 | 59.0 | 4067 | |
| | 1937 | 56.0 | 3864 | |
| | 1938 | 58.5 | 4246 | |
| Lake Washington, Washington | 1969 | 57.7 | 3638 | Ames (Pers. Comm.) |
| Lake Ozette, Washington | 1979($4_2$)[g] | 54.5 | 3193[h] | |

[a] No segregation according to age. Probably mostly $5_2$ fish. According to Foskett (1956), Skeena River sockeye in these years were 72, 82, and 76% $5_2$ fish, respectively.

[b] Both $4_2$ and $5_2$ fish involved.

[c] Egg counts not correlated directly with length of females. Hence, mean lengths of females, as recorded for the sockeye examined at the mouth of the Ozernaya River, are used. No age separation has been made.

[d] Only four individuals in the sample.

[e] Only ranges in length and egg content available. For lengths, males and females are combined. Neither for length nor egg content is there any segregation according to age. Several year-classes are involved.

[f] Figures in parentheses indicate the number of specimens.

[g] Figures in parentheses indicate the age of the fish on the Gilbert system

[h] Only eight individuals in the sample.

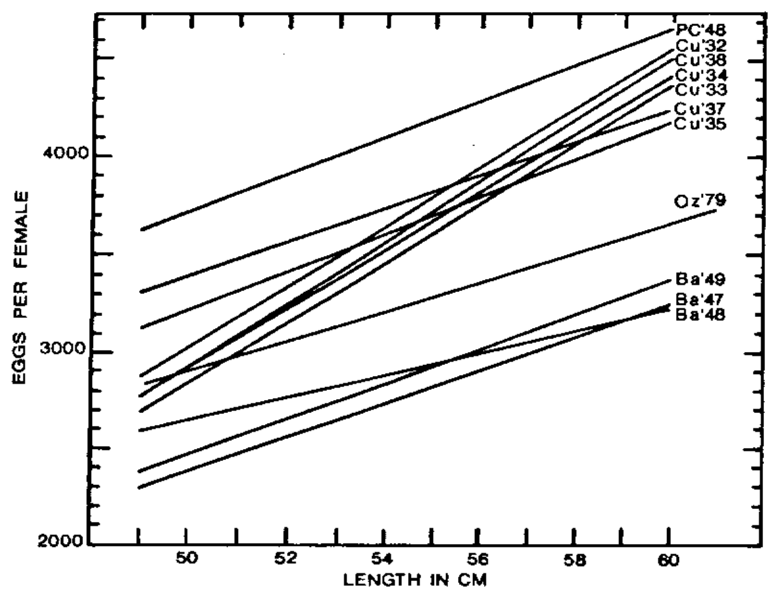



Figure 8. Regression lines depicting the relationship of egg content (fecundity) of sockeye salmon to size of female for: (1) Cultus Lake, (2) Babine Lake, (3) Pick Creek, Alaska, and (4) Ozette Lake, Washington populations in the years indicated.

TABLE 4.--The length of incubation periods and the number of Fahrenheit "degree-day" units involved, for sockeye salmon reared in hatcheries in British Columbia (1 Fahrenheit degree-day = 5/9 Centigrade degree-day).

| Location of hatchery | Year[a] | Date when first eggs taken | Date of first hatch | Period of incubation | Degree Days |
|---|---|---|---|---|---|
| | | | | (days) | |
| Anderson Lake, west coast of | 1928-29 | Oct. 25 | Jan. 25[b] | 92 | 1168 |
| Vancouver Island | 1929-30 | Oct. 19 | Jan. 25 | 98 | 1291 |
| Babine Lake (Skeena River) | 1929-30 | Sept. 9 | Oct. 29 | 50 | 993.5 |
| Lakelse Lake (Skeena River) | 1928-29 | Aug. 4 | ? | — | 1220.5 |
| | 1928-29 | Aug. 22 | ? | — | 1231 |
| | 1929-30 | July 28 | Oct. 26 | 90 | 1333 |
| Kennedy Lake, west coast of | 1928-29 | Oct. 24 | Feb. 7 | 106 | 822 |
| Vancouver Island | 1928-29 | Nov. 9 | Feb. 27 | 110 | 707 |
| (early run) | 1929-30 | Sept. 3 | Nov. 16 | 74 | 1296 |
| (Late run) | 1929-30 | Oct. 29 | Feb. 22 | 116 | 1040 |
| Rivers Inlet, near the outlet | 1928-29 | Sept. 30 | Feb. 9 | 133 | 766 |
| of Owikeno Lake | 1928-29 | Oct. 1 | Feb. 1 | 123 | 730 |
| | 1928-29 | Oct. 9 | Feb. 18 | 132 | 697 |
| Pitt Lake (Fraser River) | 1929-30 | Sept. 2 | Oct. 29 | 57 | 1085.5 |
| Cultus Lake (Fraser River) | 1928-29 | Nov. 1 | Apr. 6 | 156 | 623.5 |
| | 1929-30 | Oct. 30 | Apr. 19 | 171 | 1199.5 |
| | 1929-30[c] | Nov. 15 | Apr. 5 | 141 | 1043.5 |
| Pemberton (Fraser River) | 1929-30 | Sept. 9 | Dec. 28 | 110 | 955.5 |
| Stuart Lake (Fraser River) | 1929-30 | Aug. 28 | Oct. 26 | 59 | 1098 |
| Lake Ozette, Washington | 1978-79 | Jan. 4[d] | Apr. 17[e] | 68-82[f] | 987.8-1215.2[f] |

[a] Year commenced July 1.

[b] Eggs "eyed" Nov. 29 after 519 units.

[c] These eggs were transferred to and reared in a subsidiary hatchery at Smith Falls.

[d] Eggs deposited.

[e] First fry emergence.

[f] Assuming hatching occurs 3-5 weeks prior to emergence.

We continued our search for the virus by examining the progeny. On February 20, 1980 we used a hydraulic sampler to procure eyed eggs from known redds. Four hundred eyed eggs were transported to the FWS National Fisheries Research Center, Seattle, Washington where the eggs were hatched and fry reared. In late April, IHN virus was detected in fry from the Lake Ozette sockeye population.

Plankton Surveys

Sockeye fry, subsequent to emergence and after a brief littoral residence, migrate to limnetic regions where it is recognized that zooplankton serve as their major food source. Particularly important are the adult crustaceans of the orders copepoda and branchiopoda. Rotifera play an apparently insignificant role in sockeye energy budgets (Foerster, 1925; Ricker 1938).

*Diaptomus sp., Epischura sp.,* and copepods of the genus cyclopoida occurred in all samples. Cladocerans present in all samples included: *Bosmina sp., Daphnia sp., Holopedium sp.,* and *Leptodora kindtii.* During this study, copepods and cladocerans comprised from 57.0% to 99.8% of the organisms in monthly samples.

Two species of large cladocerans, *Leptodora kindtii* and *Holopedium sp.,* increased in density during summer months, and coincided with peak feeding activity of juvenile sockeye. Although these two species were never as common as the copepods or other cladocerans, they are certainly prey organisms that provide maximum return of energy for the amount expended in pursuit and capture by pre-smolt sockeye. Doble and Eggers (1978) and Eggers (1978) at Lake Washington, and Foerster (1925) working at Cultus Lake, British Columbia, noted that *Leptodora kindtii* were stratified in large concentrations 3 m below the surface. Thus, in spite of the occurrence of relatively few *Leptodora kindtii* and *Holopedium sp.* in our vertical haul samples (Figure 1), it is conceivable that they are present in larger concentrations at other depths.

Instantaneous standing crop estimates of copepods and cladocerans expressed as organisms/liter are illustrated in Figure 9. The trend is one of low winter levels, increasing densities through spring and summer, followed by a decline in the fall. This is a common situation for temperate latitude lakes (Reid 1961). It is also important to note that a spring pulse in zooplankton production occurs in May and June, thus providing food for newly-emerged sockeye fry at a critical period in their development.

Zooplankton standing crop is not synonymous with productivity, but it is nevertheless useful to examine standing crop as it relates to sockeye smolt production. Generally, high zooplankton densities result in high smolt production (Brannon 1972). Accordingly, we compared several physical parameters, average summertime zooplankton abundance, and smolt production of six lakes in Canada, Alaska and Russia with Lake Ozette (Table 5). The density values for Lake Ozette equal those of Lake Port John and surpass those of Lakes Blizhnee and Lakelse.

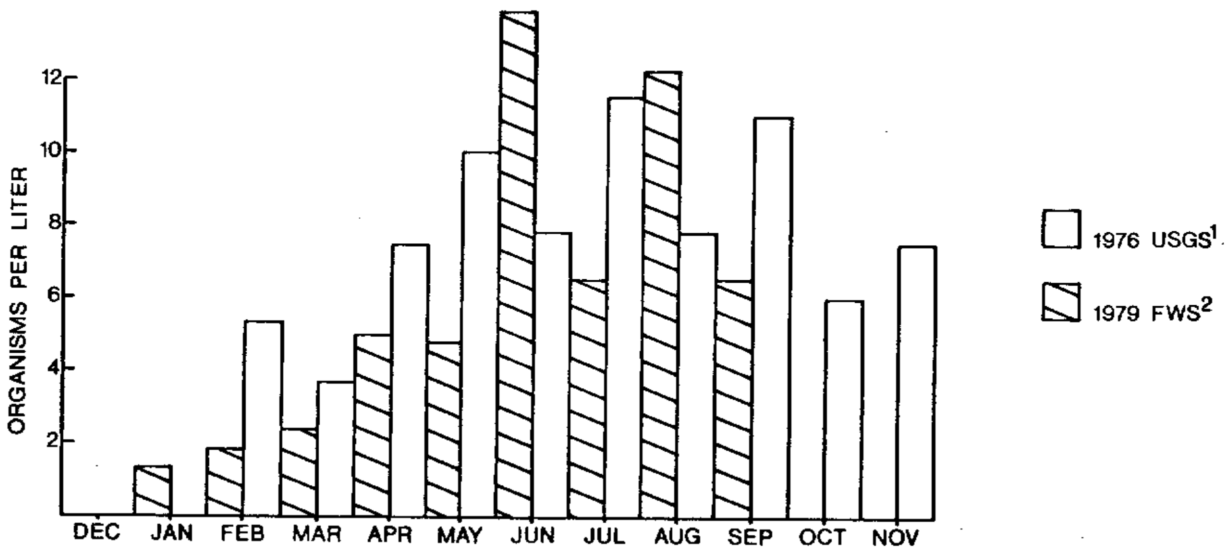



Figure 9. Average monthly zooplankton abundance, 1976 and 1979.

TABLE 5.--Average monthly abundance of zooplankton in seven lakes. Quantities are per liter of water. All values are from July to September.*

| | Cultus[a] B.C. | Lakelse[b] B.C. | Port John[c] B.C. | Karluk[d] Alaska | Dalnee[e] Kamtchatka | Blizhnee Kamtchatka | Ozette[g] Wash. |
|---|---|---|---|---|---|---|---|
| Area | | | | | | | |
| (acrea) | 1,550 | 3,520 | 224 | 9,720 | 366 | -- | 7,300 |
| (Hectares) | 627 | 1,425 | 91 | 3,934 | 136 | -- | 2,954 |
| Volume ($m^3 \times 10^6$) | 201 | 22.4 | 22.8 | 1,920 | 42.8 | -- | 1,184 |
| Depth, maximum (m) | 42 | 25 | 49 | 126 | 60 | -- | 98 |
| Depth, mean (m) | 30 | 6 | 25 | 4.8 | 31.5 | -- | 39.6 |
| Copepoda | 12.2 | 5 | 7.1 | 12.6 | 11.3 | 5.1 | 6.25 |
| Cladocera | 4.2 | 0.66 | 0.57 | 2.4 | 2.1 | 0.4 | 1.14 |
| Total | 16.4 | 5.66 | 7.67 | 15.0 | 13.4 | 5.5 | 7.39 |
| Smolt production[h] | 878.3 | 551.2 | 2.8 | -- | 90.3 | -- | 9.6[i] |

* From Foerester (1968), P. 225.

a - Average for 3 seasons

b - Average for 1 season

c - Average for 2 seasons

d - Average for 4 seasons

e - Average for 2 seasons

f - Average for 1 season

g - Average for 2 seasons

h - Mean no. ($\times 10^3$) of 1 + sockeye smolts

i - Data from 1977 brood only

Examining average yearly smolt production serves to illuminate the potential sockeye production of Lake Ozette. Of these lakes, Cultus and Lakelse produce the most sockeye smolts; however, Lakelse zooplankton densities are below those found in Ozette. Lake Ozette, with a smolt production of 9,600, does not appear to be producing sockeye to its potential in light of zooplankton densities. Assuming other factors are equal, it appears that spawning recruitment is a limiting factor rather than food supply.

## Benthic Studies

Given specific circumstances when sockeye inhabit areas of low zooplankton abundance, notably during initial lacustrine fry residence and smolt outmigration, they have been noted to feed upon midges of the family Chironomidae (Chapman and Quistorff 1938; Rogers 1961). Furthermore, Ricker (1941) while conducting studies at Cultus Lake, British Columbia, hypothesized that chironomids may serve as an alternative prey item for normally piscivorous species, such as cutthroat trout or northern squawfish, when sockeye numbers are low. Ricker found the number of chironomid larvae and pupae (combined) per square meter during March to be 460.

Working at Lake Ozette, LaGory (1979) found chironomidae and oligochaeta to be the predominant profundal organisms during late February and early March (Table 6). A total of 298 chironomid larvae per square meter of bottom for the 26 sample sites was calculated. It is possible that midge larvae may also serve as an alternate food for juvenile sockeye in Lake Ozette.

## Smolt Characteristics

A measurement to effectively assess the rearing capability of a freshwater system is a ratio of adult spawners to the quantity and quality of smolts produced; i.e., successful production is directly associated with the numbers of adult spawners, growth in the lake, and the period of lake residence.

A Lake Ozette pre-smolt population assessment was attempted by the Fisheries Research Institute (Thomas, personal communication, 1979-1980). The population estimate derived was $2.2 \times 10^6$ fish. This estimate was at least an order of magnitude more limnetic fish than could be accounted for from the known sockeye escapement of 1,000 fish. Kokanee and other fish species were probably interspersed with the sockeye population. Tow netting was attempted in order to determine the percentage composition of the acoustic targets, but these attempts were unsuccessful. These failures at acoustic assessment of juvenile population size led us to attempt the capture of smolts in the Ozette River 0.3 km downstream from the lake, using a rigid frame fyke net with a live trap (Figure 3 ).

In 1979 the net was fished from April 3 through May 29. Four 24-hour sampling sessions were conducted throughout this period. Smolts were observed to migrate only between dusk and dawn. Smolt outmigration peaked

Table 6. Profundal fauna, depth, and bottom types from 26 sampling locations in Lake Ozette, during late winter, 1979.

| Stations | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bottom Type | 2 a | 2 a b c | 2 3 a b | 2 a b | 1 a b | 2 a b | 2 a b | 1 a b | 1 4 a | 1 a b | 1 a b | 4 a b c | 1 4 a | 5 b | 5 1 | 1 b | 1 b | 3 a b | 1 a b | 1 4 a b | 1 a b | 1 a b | 1 a b | 1 4 a b | 1 a b | 2 b |
| Depth (m.) | 5.0 | 6.5 | 12.0 | 16.5 | 30.5 | 14.0 | 25.8 | 45.0 | 61.0 | 77.0 | 80.0 | 27.0 | 43.0 | 18.0 | 41.0 | 70.0 | 15.0 | 18.0 | 31.0 | 50.0 | 63.0 | 81.0 | 35.0 | 46.0 | 64.0 | 22.0 |
| Platyhelminthes | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Turbellaria | | | | | | | | | | 1 | | | | | | | | | | | | | | | | |
| Nematoda | 6 | 5 | 1 | | | | | | | | | 22 | | | | | | 1 | | | | | | | | |
| Annelida | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Oligochaeta | 21 | 12 | 11 | 3 | 4 | | 4 | 2 | 31 | 19 | 5 | 27 | 13 | 1 | | 1 | 2 | 7 | 2 | 3 | 13 | 9 | 1 | 2 | 7 | 1 |
| Hirudinea | | | | | | | | 1 | | | | 2 | | | | | | | | | | 2 | | | | |
| Anthropoda* | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Crustacea | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Branchiopoda | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diplostraca | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cladocera | 1 | | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| Ostracoda | 4 | | | | 2 | | 1 | | 2 | 1 | | 2 | | | | | | | | 3 | | 4 | | | | |
| Copepoda | | | | | | | | | | | 1 | 4 | | | 1 | | | 1 | | 1 | 4 | 1 | | 1 | 1 | |
| Malacostraca | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Eumalacostraca | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Peracarida | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Isopoda | | | | | | | | | | 2 | | 1 | | | | | | | | 2 | 1 | | | | | |
| Amphipoda | | 4 | | | | | | | | 1 | | | | | | | | | | | | | | | | |
| Insecta | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Collembola | | | | | | | | | | | | 24 | | | | | | | | | | | | | | |
| Plecoptera | | | | | | | | | | | | 3 | | | | | | | | | | | | | | |
| Homoptera | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aphididae | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| Eriococcidae | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| Coleoptera | | | | | | | | | | | | | | | | | | | | | | | | | | |
| larvae | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| adult | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| Trichoptera | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Leptoceridae | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Oecetis sp. | 1 | 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| Diptera (larvae) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Simuliidae | | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| Chironomidae | 38 | 35 | | | 3 | 2 | 5 | 3 | 7 | 3 | 1 | 30 | 1 | 4 | 8 | | 4 | 9 | 5 | 1 | 6 | 6 | 2 | 3 | 2 | 2 |
| Heleidae | 2 | 1 | | | | | | | | | | 4 | | 1 | | | | | | | | | | | | |
| Empididae | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Ephydridae | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| unknown (pupae) | | | | 1 | 2 | 5 | | 1 | | | | 1 | | | 2 | | | | | | | | 1 | | | |
| Unidentified insects | | 3 | 2 | 2 | | | | | | | | 3 | | | | | | | | | 1 | | | | | 1 |
| Arachnoidea | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acari | 1 | | | | | 1 | 2 | | | | | 6 | | | | | | 2 | 1 | | | | | | | 1 |
| Mollusca | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Gastropoda | | | | | 2 | | | 1 | | | | 5 | | | | | | | 1 | | 1 | | | 1 | | |
| Bivalvia | 15 | 4 | | 3 | 2 | 1 | 4 | 3 | 3 | 1 | | 6 | | | 2 | | 8 | 17 | 3 | 3 | 4 | | | 3 | 2 | 2 |
| Diptera head capsules* | 5 | 1 | 5 | 45 | 30 | 45 | 45 | 1 | 1 | 20 | 10 | 15 | 35 | | 85 | 10 | 5 | 25 | 30 | 5 | 10 | 20 | 10 | 15 | 5 | 65 |
| Empty Trichoptera cases | | | | | | | | | | | | | | | | | | | | | | | | | | |
| large | 34 | 54 | | 1 | | 4 | 1 | 1 | | | | 8 | | | | | 1 | | | | | | | | | |
| tiny, of sand grains* | 700 | 410 | 85 | 15 | | 75 | 15 | 1 | 5 | | | 50 | 10 | 20 | 20 | | 10 | 410 | 70 | 10 | | | | | | 5 |
| Insect egg cases | | | | | | | | | | | | | | | | | | | | | | | | | | |
| round* | 5 | | 1 | | | 125 | 120 | 15 | 35 | 60 | 25 | 65 | 75 | 5 | 125 | 40 | 30 | 35 | 175 | 85 | 180 | 155 | 130 | 110 | 200 | 1 |
| flattened | | 1 | | | | 1 | | | | | | 3 | | | | | | | | | | | | | | |
| Unidentified eggs | | | | | 7 | 5 | 12 | 2 | | 50 | 25 | 16 | 15 | | | 10 | 25 | 2 | 22 | 14 | 25 | 30 | 66 | 27 | 16 | 5 |

* Number given is an estimate

Materials Present in Sediment

a - mucous-fine sand tubes (of oligochaetes)
b - miscellaneous arthropod parts
c - decaying organisms

Bottom Type - Sediments

1. Fine, silty mud; small amount of organic debris
2. Fine, sandy mud; small to moderate amount of organic debris
3. Sand; small pebbles; mud
4. Much organic debris - leaves, twigs, etc.
5. Mostly clay; some sand

on May 6. Timing and magnitude of the sockeye outmigration is illustrated in Figure 10. To estimate net efficiency in order to determine population size, we released marked coho smolts 0.2 km above the fyke. Based on these recoveries and assuming that sockeye smolts behave in the same manner as the marked coho, we believe that 11% of all sockeye smolts were captured. The smolt outmigration for the 1977 brood was approximately 9,600.. While only a weir will provide actual production values, we believe that the fyke net provides a relatively close approximation to actual run size. Ninety-nine plus percent of the sockeye smolts were 1+ fish with an average length of 11.3 cm and an average weight of 14.2 g. The length/weight regression for these fish (Figure 11) indicates that they are the third largest sockeye smolts (yearlings) reported from the literature (Table 7 ), and are exceeded only by Lake Dalnee, Kamchatka, Alaska and Lake Washington sockeye. According to Foerster (1968) there is a strong correlation between large smolt size and high marine survival. The size of these smolts also indicated that zooplankton production is not being exhaustively cropped by juvenile sockeye or other competitors. Zooplankton production currently does not appear to be a limiting factor to sockeye production in Lake Ozette.

Sockeye Associates in Lake Ozette

Sockeye production in Lake Ozette constitutes a single segment of an active and dynamic community of fishes. The interrelationships (competition and predation) may be active during the total Lake Ozette residence or temporary, as in regard to season, location, or stage of development (i.e., fry or smolts).

A list of the fishes encountered in Ozette is presented in Table 8. Following Foerster (1968), we have grouped the fish according to location within the lake. This grouping is only a general reference as locations change with age and season. Associated fish species for 12 British Columbia lakes are also presented for comparison with Ozette. Mean lengths and weights are presented in Table 9. Length-weight relationships and back calculations of growth are presented in the Appendix.

As a method for achieving an undetstanding of the interrelationships between sockeye and the other lake fauna, we randomly sampled the lake on a monthly basis during 1978 and 1979. It should be remembered that the results (Table 10) of this sampling effort are not all-inclusive of the lake species, as those fish smaller than could be effectively captured are not represented, i.e., three spine sticklebacks and the Olympic mudminnow. However, we do believe that this survey provides a relative indication of the make-up of the littoral fish community. Analysis of variance indicated differences ($P \geq .05$), both seasonal and by habitat, in mean catch/effort (CPE) for cutthroat trout. Seasonal differences were detected for peamouth and yellow perch. However, analysis of covariance for each species yielded no significant ($P \leq .05$) differences in seasonal trends for any of the three habitat types, indicating a random distribution.

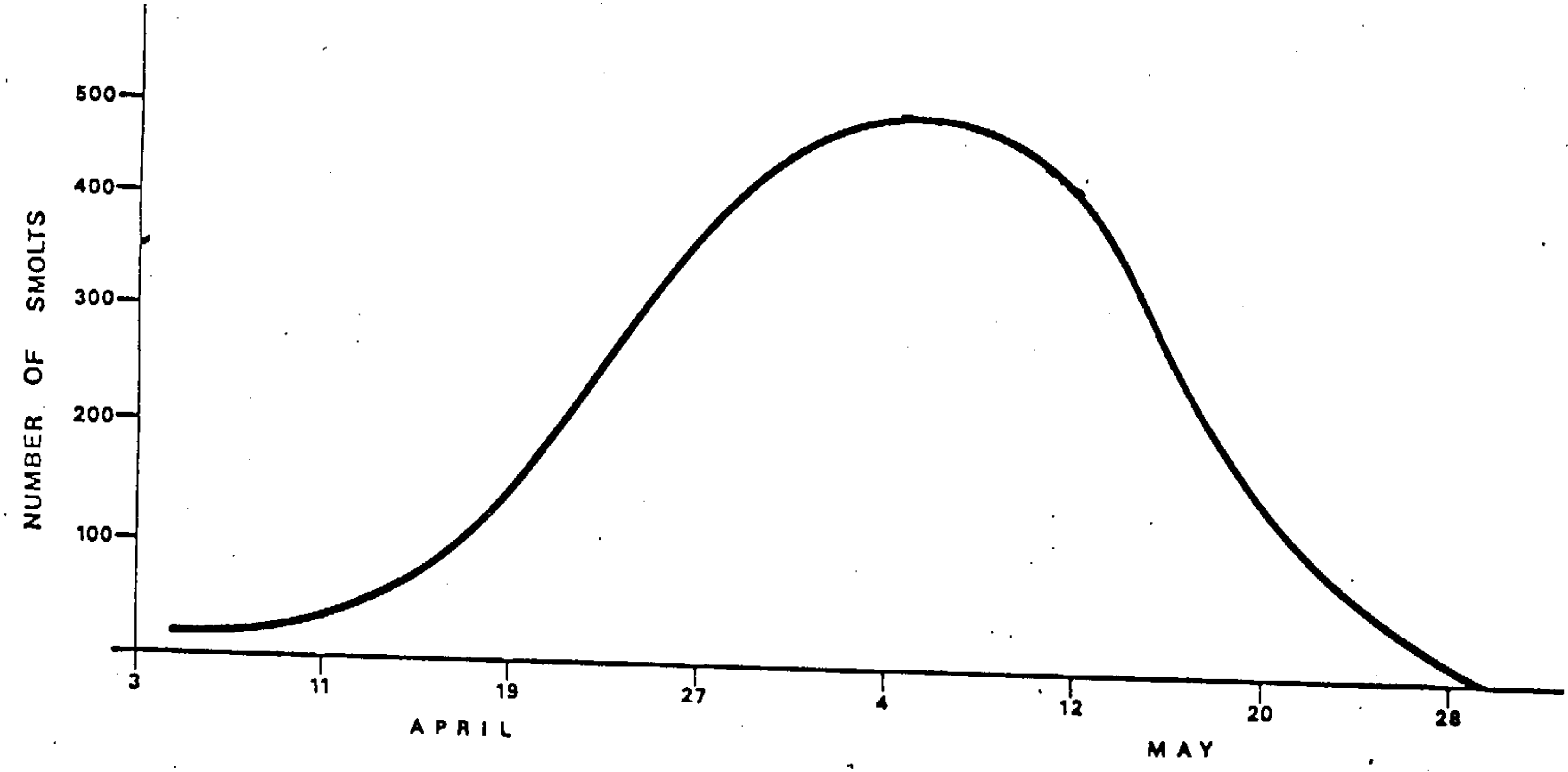
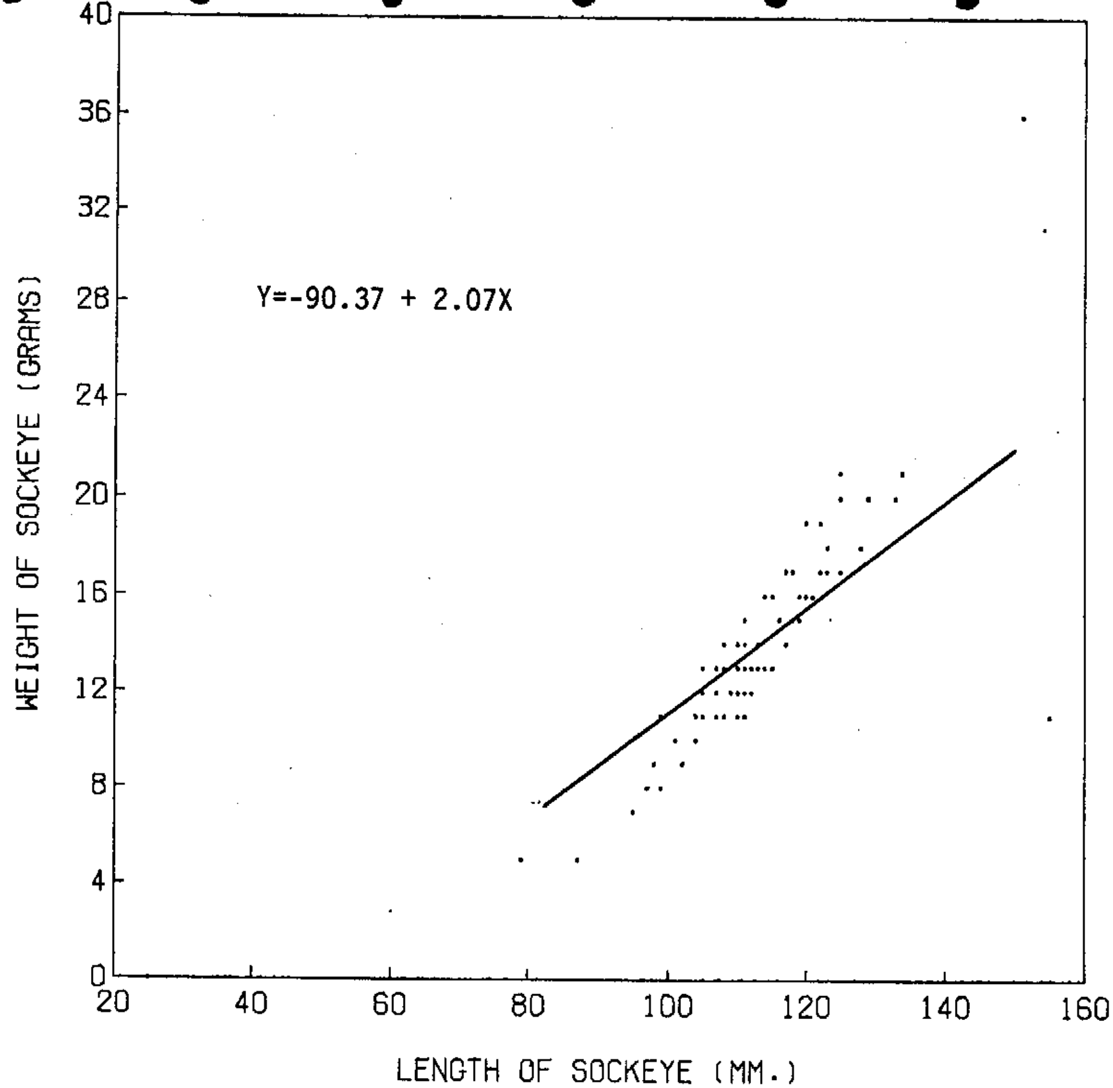



Figure 10. Timing and abundance of the 1979 (1977 brood) smolt production.




LENGTH VERSUS WEIGHT 95 VALUES

Figure 11.

1977-79 SOCKEYE SMOLTS, LAKE OZETTE

Table 7. Average lengths and weights of seaward-migrating sockeye of age 1 (yearlings).

| Region and Lake | Avg length (cm) I | Avg wt (g) I | Number of years' data | References |
|---|---|---|---|---|
| Fraser System | | | | |
| Cultus | 8.5 | 6.3 | 11 | Foester, 1944, p. 272 |
| Harrison | 9.5 | 9.2 | 2 | Clutter & Whitsel,'59, p.24 |
| Lillooet | 7.7 | 4.5 | 1 | " |
| Shuswap | 6.3 | 2.3 | 2 | " |
| Chilko | 7.6 | 4.3 | 5 | " |
| Francois | 10.5 | 12.0 | 1 | " |
| Stuart | 9.5 | 8.4 | 1 | " |
| Skeena System | | | | |
| Lakelse | 8.2 | 5.5 | 1 | Foester, 1952, p. 30 |
| Babine | 8.3 | 5.7 | 4 | Dombroski, 1954, p. 32 |
| Central B.C. Coast | | | | |
| Owikeno | 6.1 | 2.0 | - | Foskett, 1958a, p. 161 |
| Port John | 8.4 | 6.2 | 5 | FRBC data |
| Alaska | | | | |
| Karluk | - | - | 16 | Rounsefell, 1958a, p. 161 |
| | 11.1 | - | 6 | Barnaby, 1944, p. 274 |
| Chignik | - | - | - | FRI, 1959, p. 11 |
| Little Kitoi | 6.2 | 2.0 | 1 | ADF, 1959, p. 32 |
| Ruth[a] | 11.2 | 13.6 | 1 | " |
| Midarm | 7.2 | 2.7 | 1 | " |
| Kamchatka | | | | |
| Dalnee | 11.5 | 15.5 | ? | Krogius, 1961, p. 133 |
| Achchei | - | - | ? | " |
| Azabach | 10.0 | 9.3 | ? | " |
| Kurile | - | - | ? | " |
| Columbia System | | | | |
| Wenatchee and Osoyoos | 8.9-12.7 | - | 1 | Fish & Hanavan, 1948,p. 25 |
| Same[b] | 10.8 | - | 5 | Anas & Gouley, 1956,p.42-46 |
| Lake Washington | 12.7 | 18.5 | 5 | Eggers, 1978, p. 1121 |
| Lake Ozette | 11.3 | 14.2 | 2 | |

a - Ruth Lake had been poisoned and the scrap fish eliminated prior to planting of sockeye fry.

b - These sockeye were trapped at Bonneville Dam during the year, most of them in April and May, as they migrated down the Columbia River.

Table 8. List of fishes, other than young sockeye salmon, found in Lake Ozette and sockeye-producing lakes of British Columbia. X indicates the presence of a species.

| | | Cultus | Port John | Lakelse | Morice | Kit-wanga | Kitsum-gallum | Bear | Upper Sustut | Mor-rison | Lac-de-dah | Babine | Shu-swap | Ozette |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OPEN LAKE AREAS: | | | | | | | | | | | | | | |
| Cutthroat trout | *Salmo clarki* | x | x | x | - | x | x | - | - | x | - | - | - | x |
| Rainbow trout | *S. gairdneri* | - | x | x | x | - | - | x | x | x | x | x | x | x |
| Dolly varden (char) | *Salvelinus malma* | x | x | x | x | x | x | - | x | - | x | - | x | - |
| Coho salmon | *Oncorhynchus kitsutch* | x | - | - | - | - | - | x | x | x | - | - | x | x |
| Kokanee salmon | *O. nerka kennerlyi* | - | - | - | - | - | - | x | - | x | - | x | x | x |
| Squawfish | *Ptychocheilus oregonensis* | x | - | x | - | x | - | - | - | x | - | x | x | x |
| SHALLOW WATER: | | | | | | | | | | | | | | |
| Peamouth | *Mylocheilus caurinus* | - | - | x | - | x | - | - | - | x | - | x | x | x |
| Redside shiner | *Richardsonius balteatus* | x | - | x[a] | - | x | - | x | x | - | - | x | x | x |
| Lake chub | *Couesius plumbeus* | - | - | - | - | - | - | - | x | - | - | x | - | - |
| Longnose dace | *Rhinichthys cataractae* | - | - | - | - | - | - | - | - | - | - | x | - | - |
| Leopard dace | *R. falcatus* | - | - | - | - | - | - | - | - | - | - | - | x | - |
| Carp | *Cyprinus carpio* | - | - | - | - | - | - | - | - | - | - | - | x | - |
| Threespine stickleback | *Gasterosteus aculeatus* | x | x | x[b] | - | x | - | - | - | - | - | - | - | x |
| Prickly sculpin | *Cottus asper* | x | x | x[a] | x | - | - | x | - | - | - | x | x | x[a] |
| Coast-range sculpin | *C. aleuticus* | x | - | - | - | - | - | - | - | - | - | - | - | - |
| Yellow perch | *Perca flavenscens* | - | - | - | - | - | - | - | - | - | - | - | - | x[c] |
| Largemouth bass | *Micropterus salmoides* | - | - | - | - | - | - | - | - | - | - | - | - | x[c] |
| Olympic mud minnow | *Novumbra hubbsi* | - | - | - | - | - | - | - | - | - | - | - | - | x[c] |

a - Taken in fyke nets. b - Taken in trout and squawfish stomachs. c - Introduced species.

Table 9. Biological characteristics of competitors with, and predators on, sockeye in Lake Ozette.

| Species | No. | $\bar{x}$F.L. | $\bar{x}$Wt. | K | Age Range (years) | Relationship to Sockeye |
|---|---|---|---|---|---|---|
| Kokanee | 223 | 21.5 cm | 103.5 g | 1.03 | Spawners | Competitor |
| Yellow Perch | 549 | 18.1 cm | 95.4 g | 1.29 | 1-9 | Competitor Age 0-3 |
| Peamouth | 1,199 | 22.1 cm | 124.0 g | | 1-8 | Competitor Age 0-2 |
| Cutthroat Trout | 209 | 28.0 cm | 223.0 g | 0.94 | 1-6 | Predator |
| Squawfish | 1,081 | 29.3 cm | 342.0 g | | 1-15 | Predator/Competitor Age 0-3 |
| Prickly Sculpin | 129 | 7.5 cm | 13.4 g | | | Predator on Eggs |

Table 10. Mean catch per unit of effort (CPE) for six species, seasonally and by habitat type[1]

CUTTHROAT

| | Dec.-Feb. | Mar.-May | June-Aug. | Sept.-Nov. |
|---|---|---|---|---|
| Shallow Bays | 5.6 | 7.7 | 5.3 | 4.4 |
| Creek Mouths | 2.1 | 1.9 | 1.8 | 0.3 |
| Steep Beaches | 5.7 | 8.0 | 3.7 | 3.0 |

SQUAWFISH

| | Dec.-Feb. | Mar.-May | June-Aug. | Sept.-Nov. |
|---|---|---|---|---|
| Shallow Bays | 3.4 | 20.5 | 24.9 | 9.8 |
| Creek Mouths | 27.5 | 30.4 | 31.0 | 40.2 |
| Steep Beaches | 9.0 | 26.9 | 49.7 | 15.0 |

YELLOW PERCH

| | Dec.-Feb. | Mar.-May | June-Aug. | Sept.-Nov. |
|---|---|---|---|---|
| Shallow Bays | 1.6 | 8.7 | 36.7 | 16.0 |
| Creek Mouths | 0.6 | 13.6 | 25.4 | 9.0 |
| Steep Beaches | 2.3 | 7.0 | 10.2 | 14.4 |

PEAMOUTH

| | Dec.-Feb. | Mar.-May | June-Aug. | Sept.-Nov. |
|---|---|---|---|---|
| Shallow Bays | 23.6 | 47.5 | 31.3 | 19.0 |
| Creek Mouths | 6.7 | 54.6 | 35.2 | 22.2 |
| Steep Beaches | 26.3 | 69.1 | 21.7 | 32.6 |

KOKANEE

| | Dec.-Feb. | Mar.-May | June-Aug. | Sept.-Nov. |
|---|---|---|---|---|
| Shallow Bays | 0.1 | 0.0 | 0.2 | 0.1 |
| Creek Mouths | 0.3 | 0.0 | 0.1 | 38.8 |
| Steep Beaches | 0.7 | 0.0 | 0.2 | 5.1 |

COHO

| | Dec.-Feb. | Mar.-May | June-Aug. | Sept.-Nov. |
|---|---|---|---|---|
| Shallow Bays | 0.0 | 1.2 | 0.0 | 0.4 |
| Creek Mouths | 0.7 | 0.0 | 0.0 | 2.8 |
| Steep Beaches | 0.0 | 0.0 | 0.0 | 0.1 |

[1]Shallow bays ≤ 3 meters. Steep beaches ≥ 18 meters deep within 46 meters of shore.

Of these fish, those which compete with sockeye for zooplankton and those which prey upon sockeye have the greatest significance. These fish are discussed in the following section.

Competitors

Potential competitors with anadromous sockeye within the Ozette watershed include: kokanee, red-sided shiner, and juvenile peamouth, yellow perch and squawfish. Competition with sockeye can occur in the littoral zone, but primarily takes place in the pelagic. Eighty-one percent of Lake Ozette by area can be classified as pelagic. We utilized the 60-foot depth contour as the dividing line between littoral and pelagic zones (Ricker 1952). The summer season of rapid growth during which sockeye utilize plankton in the pelagic zone is void of all but a single competitor, the kokanee. Red-sided shiner and juvenile yellow perch, peamouth and squawfish, the other likely competitors, are largely restricted to the littoral zone, utilizing zooplankters which are probably unavailable to sockeye (Ricker 1937). During the winter, these competitors are probably intermixed with sockeye, but Ricker (1937) concludes that this is probably not deleterious " . . . as there is little growth and presumably a decreased amount of feeding."

Kokanee (*Oncorhyncus nerka Kennerlyi*) - Kokanee is a nonmigratory form of sockeye. They consume zooplankters almost exclusively, and thus represent the major potential competitor with sockeye (Withler et al. 1948). Kokanee were probably present prehistorically in Lake Ozette, as they and sockeye diverged from a common stock (Ricker 1940). Historical abundance is unknown, but a plant of silver trout (kokanee) by the Washington Department of Game (WDG) in 1958 (J. Ayerst, personal communication, 1978) resulted in these fish appearing in the sport fishery (J. Wessler, personal communication, 1979). Although some genetic experiments (Utter 1976) are being conducted in an attempt to differentiate sockeye from kokanee in lakes prior to smoltification, these attempts have not been successful.

During spawning, mid-November to early December, these fish are interspersed with sockeye on the lakeshore and also spawn in the east shore tributaries, Crooked Creek, Elk Creek, Siwash Creek, etc. (Figure 1). Spawning activity peaks in late November (Appendix 1).

At the current sockeye production level of <10,000 smolts and taking into account the average size of the smolts produced (11.3 cm and 14.2 g) kokanee do not appear to be a serious competitory threat. They may even be acting as a buffer to the sockeye crop in the face of predators. If restoration efforts are undertaken to increase sockeye production and zooplankters are being severely cropped, then the removal of kokanee can be readily accomplished on their spawning grounds.

Yellow Perch *(Perca flavescens)* - The yellow perch was introduced into Lake Ozette along with largemouth bass *(Micropterus salmoides)* and possibly the Olympic mudminnow *(Novumbra hubbsi)* in the 1940s (J. Wessler, personal communication, 1978). The perch introduction has been extremely successful, as they are the third most abundant species in the lake (Table 10).

We analyzed 113 perch stomachs to determine food habits. Clady (1974) found zooplankters in young-of-the-year perch. At Ozette we observed that perch smaller than 11.9 cm fork length (age 2) fed primarily on zooplankters, thus directly preying on the same organisms as sockeye. The diet of older fish consisted of aquatic insects (40%), benthic invertebrates (24%), fish (8%), and terrestrial insects (5%) (Table 11). The piscivorous perch consumed sculpins, young perch, and peamouth.

It is generally recognized that perch spawn in early spring as water temperatures reach the 45°F. to 60°F. range (Eddy and Surber 1943; Echo 1955; Bartoo 1972). At Lake Ozette both male and female perch were observed in advanced states of sexual development during the periods from February to May and October to December, or 8 months out of the year.

The problem in assessing the actual impact of this species is the absence of a historical data base. We can well assume that interactions shaped a fish community different in structure and function prior to the spiny ray introductions. However, the presence of perch in Lake Washington (Olney, personal communication) does not pose a threat to sockeye production and this conclusion is probably valid with regard to Lake Ozette.

Peamouth *(Mylocheilus caurinus)* - These fish are primarily bottom feeders consuming aquatic insects and benthic invertebrates (Clemens 1939). Zooplankton was found in young fish by several researchers (Brown 1971; Hill 1962); therefore, potential competition with Ozette sockeye was investigated.

Peamouth were the most abundant fish captured during our gillnetting study, with 1,199 fish captured. The distribution of Lake Ozette peamouth (Table 10) shows a high concentration in the littoral zone during summer growth periods. Ripe fish were observed in all sampling locations from mid-April to mid-June, with the highest concentrations occurring throughout the lake during May. In order of importance, the ripe peamouth were captured off gravel beaches, creek mouths, and shallow bays. As we previously reported for yellow perch, peamouth are probably not significant competitors with sockeye because of the observed inshore distribution.

Table 11. The number and percentage composition of food organisms found in the stomachs of fishes from Lake Ozette - February 1978 to April 1979.

| Food Organisms | YELLOW PERCH (examined 113) No. | Per Fish | % Comp. | CUTTHROAT (examined 98) No. | Per Fish | % Comp. | SQUAWFISH (examined 196) No. | Per Fish | % Comp. | SCULPIN (examined 74) No. | Per Fish | % Comp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AQUATIC INSECTS - TOTAL | 415 | 3.67 | 42 | 189 | 1.93 | 13.0 | 64 | .33 | 14.0 | 21 | .28 | 34.0 |
| Coleoptera (larvae) | | | | | | | 1 | .01 | Trace | | | |
| Chironomidae | 10 | .09 | 1.0 | 9 | .09 | 1.0 | 3 | .02 | 1.0 | | | |
| Corixidae | 1 | .01 | Trace | 30 | .31 | 2.0 | 1 | .01 | Trace | | | |
| Odonata (nymph) | | | | 1 | .01 | Trace | | | | | | |
| Plecoptera (larvae & adult) | 1 | .01 | Trace | 10 | .10 | 1.0 | 9 | .05 | 2.0 | | | |
| Trichoptera (larvae & adult) | 397 | 3.51 | 40 | 135 | 1.38 | 9.0 | 43 | .22 | 9.0 | 21 | .28 | 34.0 |
| Ephemeroptera (larvae) | 3 | .03 | Trace | 3 | .03 | Trace | 5 | .03 | 1.0 | | | |
| Neuroptera (larvae) | 3 | .03 | Trace | 1 | .01 | Trace | 2 | .01 | Trace | | | |
| TERRESTRIAL INSECTS - TOTAL | 52 | .46 | 5.0 | 1095 | 11.17 | 76.0 | 171 | .87 | 37.0 | 13 | .18 | 21.0 |
| Diptera | 1 | .01 | Trace | 11 | .11 | 1.0 | | | | | | |
| Hemoptera | | | | 64 | .65 | 4.0 | 5 | .03 | 1.0 | | | |
| Coleoptera (adults) | 11 | .10 | 1.0 | 97 | .99 | 7.0 | 14 | .07 | 3.0 | | | |
| Hemiptera (adults) | 17 | .15 | 2.0 | 620 | 6.33 | 43.0 | 12 | .06 | 3.0 | 2 | .03 | 3.0 |
| Hymenoptera | | | | 210 | 2.14 | 15.0 | 90 | .46 | 19.0 | 1 | .01 | 2.0 |
| Odonata (adult) | | | | 4 | .04 | Trace | | | | | | |
| Orthoptera | 2 | .02 | Trace | 1 | .01 | Trace | | | | 3 | .04 | 5.0 |
| Isoptera | 5 | .04 | 1.0 | 35 | .36 | 2.0 | 13 | .07 | 3.0 | 1 | .01 | 2.0 |
| Unknown (partially digested) | 16 | .14 | 2.0 | 53 | .54 | 4.0 | 37 | .19 | 8.0 | 6 | .08 | 10.0 |
| ZOOPLANKTON | 140 | 1.24 | 14.0 | | | | 1 | .01 | TRACE | | | |
| Spiders | | | | 8 | .08 | 1.0 | 1 | .01 | Trace | | | |
| Mites | | | | 1 | .01 | Trace | | | | | | |
| BENTHIC INVERTEBRATES - TOTAL | 259 | 2.29 | 26.0 | 61 | .62 | 4.0 | 94 | .48 | 20.0 | 4 | .05 | 1.0 |
| Bivalves | 1 | .01 | Trace | | | | 10 | .05 | 2.0 | 2 | .03 | 3.0 |
| Snails | 210 | 1.86 | 21.0 | 58 | .59 | 4.0 | 17 | .09 | 4.0 | 1 | .01 | 2.0 |
| Crayfish | 30 | .27 | 3.0 | 1 | .01 | Trace | 67 | .34 | 15.0 | 1 | .01 | 2.0 |
| Ostracods | 3 | .03 | Trace | | | | | | | | | |
| Amphipods | 9 | .08 | 1.0 | | | | | | | | | |
| Oligachaetes | 6 | .05 | 1.0 | 1 | .01 | Trace | | | | | | |
| Leeches | | | | 1 | .01 | Trace | | | | | | |
| FISH - TOTAL | 80 | .71 | 8.0 | 81 | .83 | 6.0 | 97 | .49 | 21.0 | 20 | .27 | 33.0 |
| Yellow Perch | 8 | .70 | 1.0 | 9 | .09 | 1.0 | | | | | | |
| Sockeye | | | | 8 | .08 | 1.0 | 3 | .02 | 1.0 | | | |
| Sculpins | 24 | .21 | 2.0 | 7 | .07 | Trace | 14 | .07 | 3.0 | | | |
| Coho | | | | 3 | .03 | Trace | | | | | | |
| Peamouth | 5 | .04 | 1.0 | 7 | .07 | Trace | 3 | .02 | 1.0 | | | |
| Squawfish | | | | 3 | .03 | Trace | 5 | .03 | 1.0 | | | |
| Lamprey | | | | 1 | .01 | Trace | 9 | .05 | 2.0 | | | |
| Fish Eggs | 26 | .23 | 3.0 | 6 | .06 | Trace | 15 | .08 | 3.0 | 20 | .27 | 33.0 |
| Unknown Fish Remains | 17 | .15 | 2.0 | 37 | .38 | 3.0 | 48 | .24 | 10.0 | | | |
| PLANT MATTER | 41 | .36 | 4.0 | 16 | .16 | 1.0 | 35 | .18 | 8.0 | 3 | .04 | 5.0 |
| EMPTY STOMACHS | 10 | .09 | | 1 | .01 | | 5 | .03 | | 23 | .31 | |
| PARASITES - TOTAL | 37 | .33 | | 10 | .10 | | 109 | .55 | | 15 | .20 | |
| Tape Worms | 17 | .15 | | 5 | .05 | | 73 | .37 | | | | |
| Nematodes | 20 | .18 | | 5 | .05 | | 36 | .18 | | 15 | .20 | |

## Predators

Previous sockeye enhancement work (Foerster 1941) has demonstrated a direct relationship between the numbers of smolts and predators. We observed predation on sockeye by cutthroat trout and squawfish in the lake and during the smolt outmigration in the Ozette River. Prickly sculpins, cutthroat, and peamouth were observed eating sockeye eggs on the spawning beaches, but we believe that the eggs consumed were not redd-deposited.

Cutthroat Trout *(Salmo clarki)* - Two hundred nine cutthroat trout were sampled by gill net and hook and line during the course of this study, from which 98 stomachs were examined (Table 11). In order of importance by number, the cutthroat diet consisted of: terrestrial insects, 76%; aquatic insects, 13%; fish, 8%, and benthic invertebrates, 4%. Fish made up 8% of the trout diet. Yellow perch, sockeye, and sculpins were equally taken by cutthroat. Squawfish and coho were observed half as frequently. If we assume that all of the unidentified fish remains (3% of the cutthroat's annual diet) are sockeye, then cutthroat utilize sockeye for a maximum of 4% of their total diet. In general, the larger trout consume more fish than the smaller ones (Foerster 1968). Both sea-run and resident trout were present in the lake.

Spawning fish utilize the lake tributaries and possibly the upwelling spring areas along the lakeshore. While ripe fish were captured in all months except April, August and September, we believe that a majority of the fish spawn in February and March (Irving 1956).

Squawfish *(Ptychocheilus oregonensis)* - The northern squawfish was the second most abundant fish taken in our gill net samples (Table 10). In Lake Washington it was reported (Olney 1975) that young squawfish consumed zooplankton and chironomidae, thus being competitors with sockeye. Our squawfish fry samples at Ozette consisted of only five fish removed from the stomachs of larger fish (Table 11), but we also observed these same prey items. As with the previously reported yellow perch, however, we believe that there is a spatial separation during the summer growth period and little or no competition.

We analyzed 198 squawfish stomachs from the gill net samples and discovered that by number terrestrial insects comprised 37% of the year-round diet; benthic invertebrates, 21%; fish and fish remains, 21%; aquatic insects, 14 %; and plant matter, 8%. Crayfish were the most important benthic invertebrate, comprising 15% of the total diet. This was nearly 2-1/2 times the crayfish consumed in Lake Washington (Olney 1975) by fish over 100 mm.

Ricker (1940) reports an average of 0.4 sockeye per squawfish over a 9-year period. Olney (1975) reports a 5% frequency of occurrence of sockeye over a yearly period. Of the 198 squawfish we analyzed, only three fish contained sockeye, which was 1% of the total diet. Unidentified fish remains were 10%, however, so the actual utilization of sockeye could be higher. We observed squawfish entering the Ozette River during June and this activity coincided with the cessation of sockeye outmigration. These squawfish were sexually mature. Ripe fish were also captured off gravelly beaches, creek mouths, and shallow bays (Table 10).

Prickly Sculpin *(Cottus asper)* - Cottids are known to prey on emerging sockeye fry (Foerster 1968) and under laboratory conditions (Phillips and Claire 1966) to move through redds consuming eggs and alevins.

We examined 74 sculpin stomachs during this study (Table 11). No fish were present in any of the sculpin stomachs. A third of the percentage occurrence of food items was fish eggs. Sockeye eggs were identified in four of the scuplins, but whether these were redd-deposited or loose eggs is unknown.

## Habitat Alterations

The major environmental change in the Lake Ozette watershed, which may have affected the spawning and hatching success of sockeye salmon, is suspected to be logging and associated road building practices. It is generally agreed that the production of fish is lowered under extremely high sedimentation levels primarily through the effects on embryos and fry prior to and during emergence from the gravel (Gibbons and Salo 1973).

We studied the Umbrella Creek watershed (Figure 12) for the following impacts: slash and debris accumulations, damage to streamside vegetation, streambank degradation, obstructions to fish passage, the percentage of fines in the gravel, and the amount and condition of logging roads in the basin. For the sake of brevity we are presenting only the summary of our findings; however, a detailed report (McVey 1979) with photographs documenting instream damage by river mile is available.

The Umbrella Creek basin area is 30.3 square kilometers (11.7 square miles). There are approximately 12.5 kilometers of mainstem and 7.0 kilometers of accessible tributaries. There are over 91 kilometers of logging roads in the basin. The geology of the Umbrella Creek basin is characterized by terrace deposits--fluvial and glaciofluvial sand and gravel--of Pliocene and Pleistocene age. The headwaters are underlain by marine and non-marine sandstone and siltstone of Tertiary age (Huntting 1961). Most of the road surfacing material comes from borrow pits within the Umbrella Creek drainage. This poor quality material literally crumbles under the weight of a loaded log truck and contributes to stream siltation (Cederholm 1979).

The clearcut logging of second growth and some remaining virgin timber, primarily spruce, hemlock and cedar, in the Umbrella Creek watershed has occurred rapidly since the late 1950s (Figure 13).

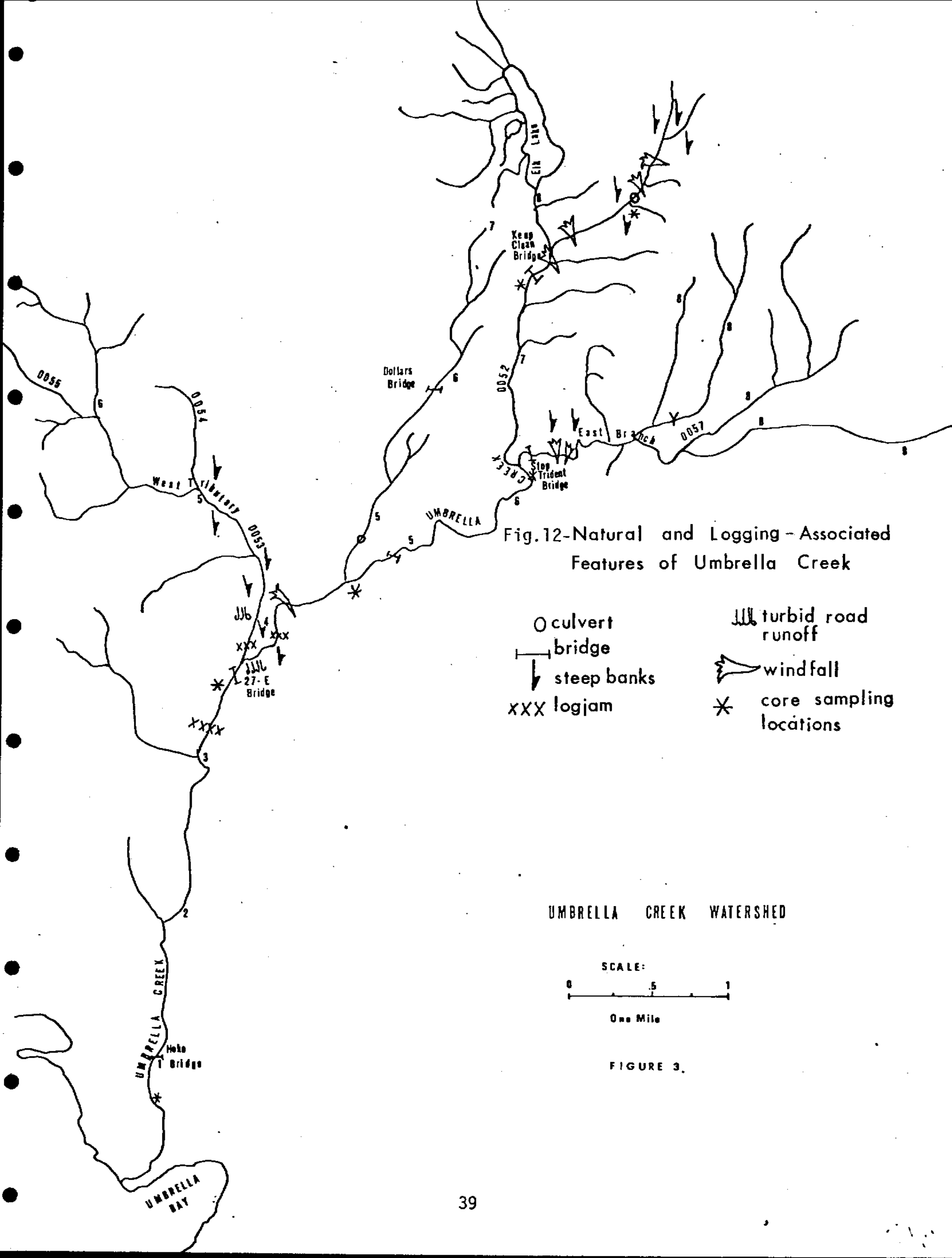



Fig. 12-Natural and Logging-Associated Features of Umbrella Creek

FIGURE 3.

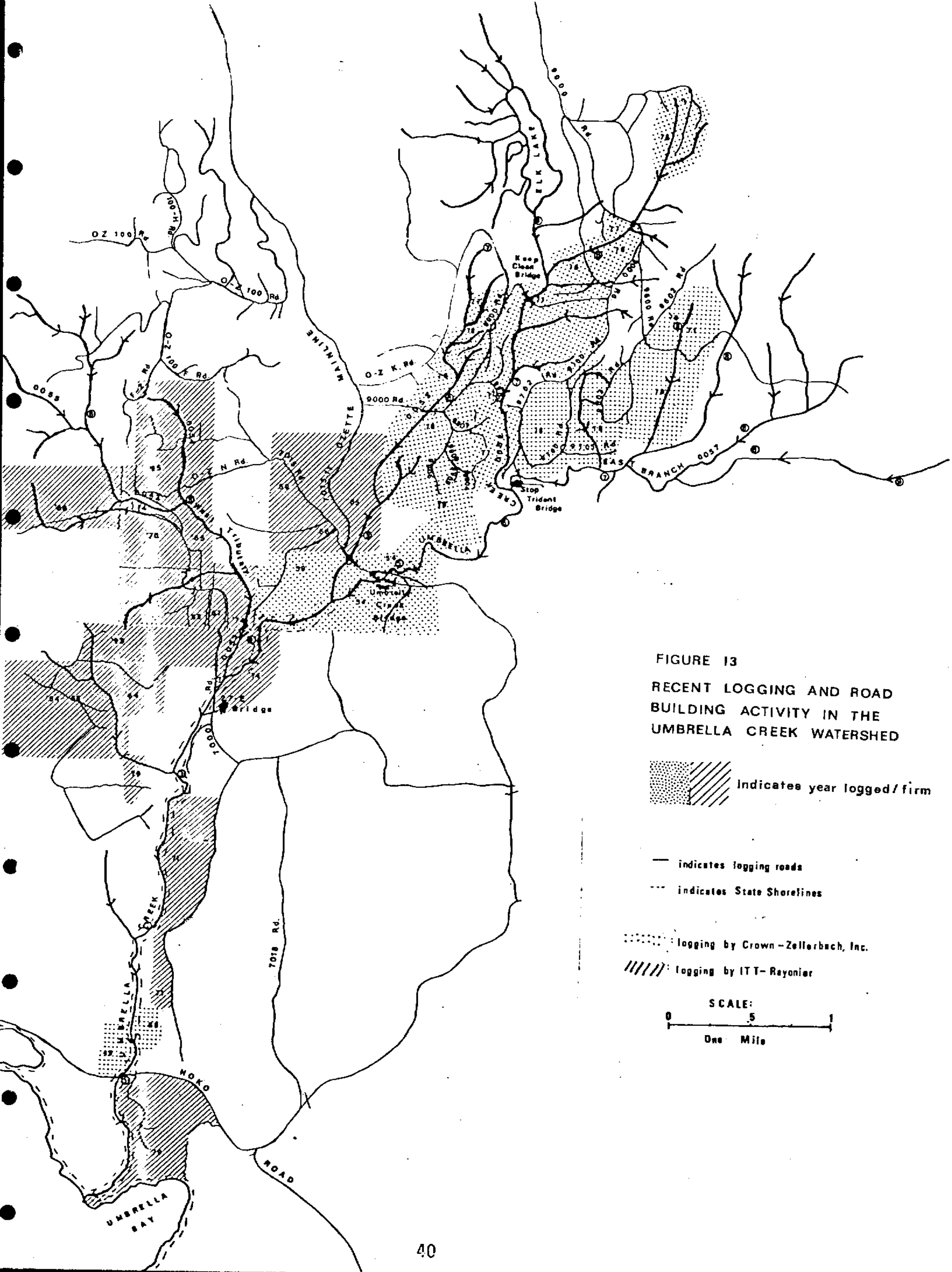



FIGURE 13

RECENT LOGGING AND ROAD BUILDING ACTIVITY IN THE UMBRELLA CREEK WATERSHED

Indicates year logged/firm

— indicates logging roads

--- indicates State Shorelines

logging by Crown-Zellerbach, Inc.

logging by ITT-Rayonier

SCALE:

0 .5 1

One Mile

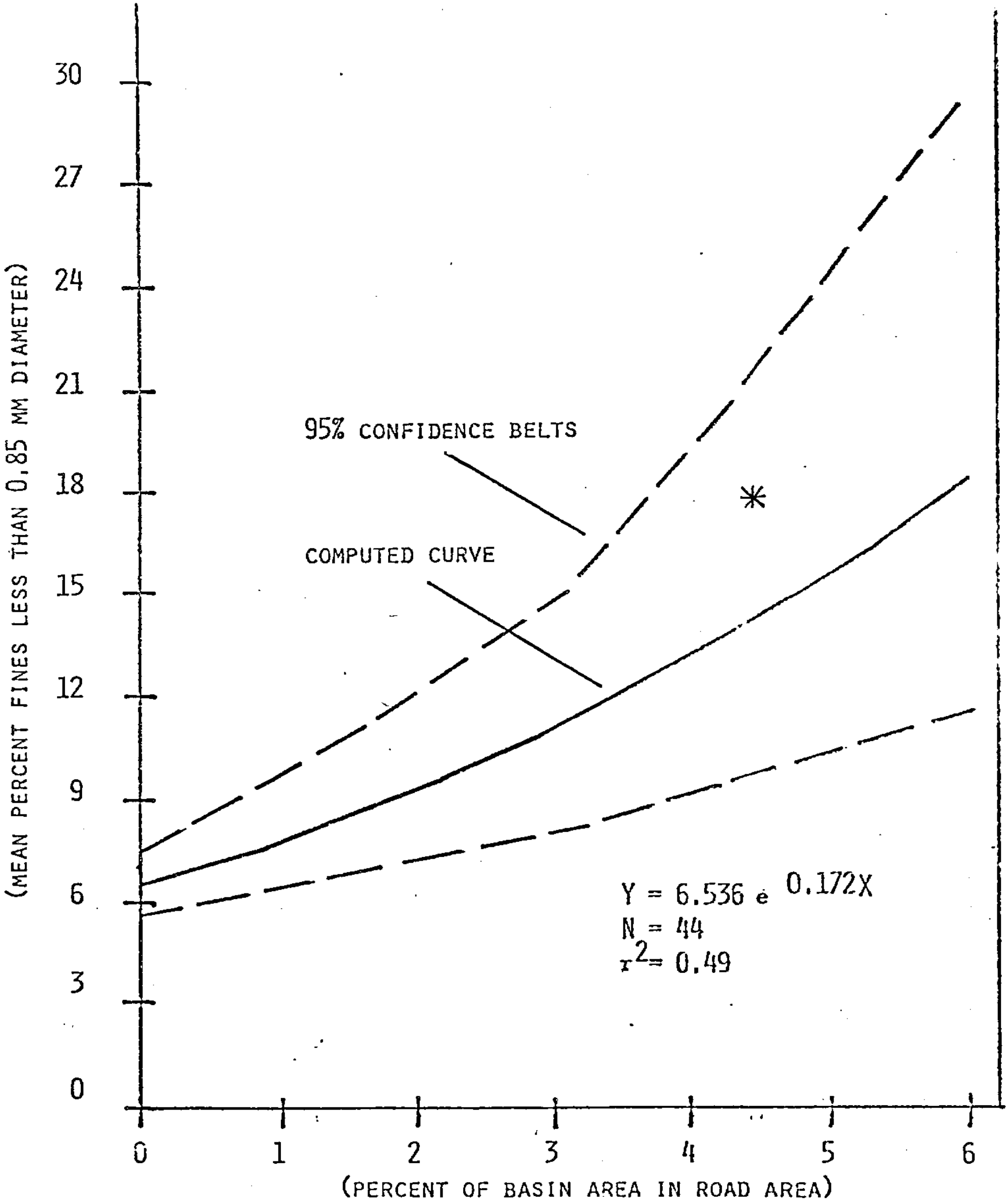



FIG. 14, RELATIONSHIP BETWEEN BASIN LOGGING ROAD AREA AND PERCENT FINES (MATERIAL LESS THAN 0.85 MM DIAMETER) IN DOWNSTREAM SALMON SPAWNING GRAVELS OF THE CLEARWATER RIVER AND SOME NEARBY STREAMS IN THE OLYMPIC NATIONAL PARK. (CEDERHOLM AND SALO, 1979).

* $\bar{x}$PERCENT FINES <0.6 mm FROM SIX SAMPLING SITES IN UMBRELLA CREEK.

We analyzed spawning gravels from six observed coho production areas in Umbrella Creek in 1979. The percentage of fine sediments (Figure 14) ranged from means of 7% to 25%. Fine sediments were defined as material passing a .6 mm sieve. Cederholm (1979) reports background fines, <.85 mm, of 3% to 10% in Olympic National Park and speculates that when the amount of logging roads exceeds two linear miles per square mile, sediments begin to accumulate in the spawning gravels. The Umbrella Creek watershed contains 4.4 linear miles of logging road per square mile, and the mean percentage of fine material from our six sampling locations in Umbrella Creek falls within the expected values for this area of the Olympic Peninsula. Other sources of sediment include bank sloughage and runoff from borrow pits.

Directional falling into Umbrella Creek and subsequent yarding of the logs has been noted, together with slash in the stream. On one occasion we noted the tracks of heavy equipment in the creek bottom. Debris jams are numerous in the creek, but do not appear to hinder coho salmon migration.

Historically, sockeye salmon spawned in Umbrella Creek (Ward, personal communication, 1977). Currently there are no sockeye utilizing this stream. Umbrella Creek has the ability to flush sediments from its gravels, once the input is reduced or curtailed. The rate at which this flushing occurs has not be determined, but our core samples (Figure 14) indicate that fines increase as one moves from the headwaters to the lake. One impact of this flushing action has been the creation of a sand bar off the mouth of the creek and the siltation of sockeye spawning grounds in the lake north of the creek mouth.

## CONCLUSIONS

The Lake Ozette sockeye population has been reduced significantly from historical levels. The sockeye formerly spawned in the tributaries to the lake but presently use only the lakeshore in areas of upwelling springs. Spawning ground surveys conducted between 1977-1979 revealed that only the lakeshore spawning component remains.

The length-weight relationship, sex ratio, fecunditv, egg-to-fry emergence and age and timing of smolts, i.e., the biological characteristics of the Lake Ozette sockeye population, are not unique when compared with other sockeye-producing systems.

Measurements of the standing crop of zooplankton indicate that the pelagic zone in Lake Ozette is not saturated with juvenile sockeye, as cropping is not taking place. In addition, there exists a spring pulse of zooplankters which are available for emerging sockeye fry. As final proof of zooplankton abundance, the size and quality of the smolts produced are one of the largest for 1+ sockeye smolts, as reported in the literature.

Competition and predation do not appear to have a limiting effect upon sockeye during lake residence, but predation upon smolts may be causing some reductions.

Siltation of the lake tributary spawning grounds in the Umbrella Creek watershed has caused a cementing of spawning gravels, and appears to be correlated to the amount of logging roads in the basin.

From the above, we conclude that a combination of overfishing and habitat degradation have reduced the sockeye population to its current level of less than 1,000 fish, and we can assume that the lake is producing at less than potential.

## MANAGEMENT ALTERNATIVES

The alternatives discussed include: I) no action; II) rehabilitation utilizing existing stocks; and III) importing outside stocks.

The management agencies expected to be involved in rehabilitation activities would include the Makah Tribe, WDF, National Marine Fisheries Service (NMFS) and FWS. We expect that the levels of commitment will vary by agency, depending on the alternative.

### Alternative I - No Action

This is the current situation. We expect that the sockeye population will remain in the 600-to-1,000-fish range, but environmental changes could alter the population dramatically.

### Alternative II - Rehabilitating the Existing Sockeye Stock

The existing stock of sockeye salmon are lakeshore spawners utilizing the upwelling spring areas in the lake (Figure 5). The origin of this stock is either native Ozette, Baker River, or Quinault Lake, or a hybridization of the three. Baker Lake 1936 brood year sockeye were planted into Ozette Lake at the following levels: 250,000 1-inch fingerlings; 125,000 2-1/2-inch fingerlings; 74,000 3-inch fingerlings (Kemmerich 1945). Quinault Lake sockeye were also planted, according to Kemmerich, but we have no records of plantings or success.

The options that can be pursued to enhance the native stock include: (1) improve egg-to-fry emergence on the three spawning beaches; (2) remove predatory fish during smolt outmigration; and (3) improve the survival by artificial rearing of the fish from egg to smolt.

#### Improve Egg-to-Fry Emergence

Investigation of the dynamics of the spawning areas utilized by the beach spawners will include the following measurements:

a. Temperature monitoring of the upwelling spring water. This parameter is probably the most important in terms of defining the spawning beach available, as we can expect that sockeye will not utilize beach areas, even if gravel size is correct, where temperature regimes are not suitable. The result of this investigation will allow us to literally stake out potential lakeshore spawning areas.

b. Spawning gravel evaluation -- Freeze core samples will be required from the three spawning beaches and other potential spawning areas associated with upwelling springs along the lakeshore. The cores will allow us to determine the percent of fines in the gravel mix. Gravel cleaning operations can then be recommended in order to improve hatching success.

c. Improve spawning gravel quality -- Test areas will be established on the three spawning beaches to determine if improving the gravel quality increases production. Spawning pairs can be placed in net pens in the improved gravel areas. Hydraulic sampling following emergence will allow us to evaluate the test and control areas. If results from this experiment show a marked increase in survival, then gravel maintenance may become an integral and ongoing part of the Lake Ozette sockeye management plan.

Remove Predatory Fish During Smolt Outmigration

Foerster's (1968) observations regarding predation led him to the following conclusion:

> Since there is a close, direct relationship between the number of seaward-migrating young (generally called "smolts") and the return from the sea of adults, the most important predators are those which prey on the young sockeye just prior to or during seaward migration. In any attempt to increase sockeye production, these predators should have first attention leading to reduction in numbers. All predators, however, are of significance and their depredations should be limited as much as possible.

The removal of predatory fish can be attempted with gill nets, traps, and seines in the vicinity of the lake outlet and the river itself during smolt outmigration and on the squawfish spawning ground.

Intensive Culturing

Raising sockeye from egg to smolt has great appeal because natural mortality can be reduced in a controlled hatchery environment. The young sockeye can be raised with adequate food under ideal water quality parameters and predation eliminated. However, attempts at artificially rearing sockeye have not been successful in increasing the production of smolts over levels achieved from natural propagation (Foerster 1938). Hatchery construction is capital-intensive, and the costs would need to be amortized over a significant time period. Hatchery propagation of sockeye, however, (Mulcahey, personal communication, 1980) has resulted in epizootics of IHN virus, which forced a curtailment of the hatchery operations. Presently, WDF is planning to construct a sockeye hatchery on the Cedar River. If technological and fish cultural solutions to the hatchery production of sockeye are forthcoming, then perhaps the sockeye population at Ozette should be propagated in a hatchery environment. It is important to reiterate that utilizing the native stocks will not take advantage of the available spawning habitat in the tributary streams, as the existing stock is genetically suited only for lakeshore spawning. Although this premise has not been tested with the Lake Ozette stock, Brannon's work in British Columbia leads us to believe that an attempt to move lakeshore spawners into the lake tributaries would not be successful.

## Alternative III - Importing Outside Stocks

The importing of an outside stock of salmon requires that various conditions be met not only to ensure that the imported seed stock survives, but that damage does not occur to the existing resources. The following conditions will need to be met in order to ensure the success of the transplant.

### Stock Selection

The WDF ( W. Wood, personal communication, 1979) estimated that Umbrella Creek and Big River could support 23,000 (±6,500) redd sites. Our spawning ground surveys indicated that the lower two miles of Siwash Creek are also available for sockeye spawning; 2,000 (±560) redd sites are suitable in this stream. In order to exploit this spawning ground potential, we propose importing a sockeye stock that is suited for tributary spawning. As we previously indicated, the Ozette stock does not appear to be genetically suited for this purpose. Eyed eggs from a pure donor stock will be planted in Netarts-type egg boxes in Umbrella Creek and placed directly in the gravel in Siwash Creek and Big River.

Netarts boxes will be required for enhancement in the Umbrella Creek watershed because the percentage of fines (particles smaller than 0.6 mm) varied from 7% to 24% in five core samples obtained from the watershed. Generally, salmonid eggs will suffer a mortality of 85% when fines approach 15% to 20% (Bell 1973). The Netarts egg boxes will be utilized until Umbrella Creek spawning conditions improve, either naturally over time, or through rehabilitation efforts. Construction of a spawning channel may be appropriate if conditions in Umbrella Creek are slow to improve. Siwash Creek and Big River have areas of low sediment and may be suitable for direct eyed egg plants. Emergent traps and fyke nets will monitor the migration to the lake. We will utilize a hydraulic sampler to determine the egg-to-fry survival after emergence.

The imported stock should arrive on the tributary spawning grounds prior to the lakeshore spawning sockeye. This will ensure that the chance of hybridization is minimized. Ideally, tributary spawning should commence in November, prior to the spawning time of the lakeshore stock.

The run timing of the imported stock should not significantly overlap the existing run. This timing differential will allow the fishery managers to establish harvest rates that will exploit lakeshore and tributary spawners at the proper levels. Gill net catches plus the use of the counting facility at the lake, or a tribal weir on the reservation, will provide the fishery managers with information on total run size. Escapement can thus be assured and sport and tribal harvestable sockeye allocated. The sport harvest will occur in the river and lake.

The stock selected should not contribute significantly to offshore fisheries, so that the probability of the stock perpetuating itself is maximized. This would preclude the selection of the Adams River stock which is harvested by the Canadian troll fleet as it migrates south along Vancouver Island.

Disease Considerations

Epizootics of IHN virus have occurred in association with various sockeye cultural efforts. The FWS sockeye hatchery on Lake Quinault, which was operated until the early 1950s, probably failed because of this disease (Mulcahey, personal communication). Best management practices will be employed to minimize this concern. The guidelines for these practices are from Dan Mulcahey, virologist with the FWS, National Fisheries Research Center, Seattle. Basically, the guidelines require analysis of each female selected for spawning. The washed, fertilized, and water-hardened eggs will be incubated separately until IHN levels from ovarian fluid samples are checked. IHN titers $\geq 10^4$ eggs will be rejected and the eggs destroyed. The low titer $\leq 10^3$ green eggs will be held at the lab until eyed, then transported to the lake for the remaining incubation. This "state of the art" practice will be necessary for all imported eggs. A side benefit of lake restoration utilizing tributary spawning fish is that IHN research will continue, and hopefully a chemical treatment or a form of immunization will be discovered. State federal guidelines will be followed with regard to importing stocks.

Planting Levels

Once a suitable stock of sockeye that meets the above criteria is located, it will be necessary to import eggs at a level that will improve the chances of restoration success. Monitoring the production levels of an imported stock and establishing the run in the lake requires that the experiment be attempted with a plant of 2 to 5 million eggs (E. Brannon, personal communication, 1980.) Several benefits will accrue from a stock transfer of this magnitude. Primarily, Lake Ozette will experience a two- to five-fold increase in sockeye. Secondly, an increased production of smolts can be recognized as tributary stock plants and not a fluctuation of lake-shore spawners, as we would expect to see several orders of magnitude more spawners than are now present. Finally, the odds of fish adapting to this new environment are increased with a plant of this level. Sockeye have a four-year life cycle. Therefore, plants of 5 million eggs/year for two life cycles (8 years) increases the chances of successful adaptation.

## RECOMMENDATIONS

There are only three sockeye-producing lakes in Washington state -- Quinault, Washington, and Ozette. We believe that in order to take advantage of the plankton production in the pelagic zone of Lake Ozette and return the lake to its historic sockeye production level, Management Alternative III be adopted.

This alternative calls for the importation of 2 to 5 million eyed eggs of low IHN titer from a stock that is genetically suited for tributary spawning. The Makah Tribe should be the lead agency and, as such, responsible for harvest management (in cooperation with the state). The tribe, with FWS and WDF assistance, should procure a suitable stock of tributary spawners for restoration. FWS should perform the disease analysis upon the stock. FWS, WDF and the tribe should monitor the success of the restoration effort.

Estimated Costs/Benefits (in 1979 Dollars) for Management Alternative III

Costs:

| | Per Year | 8-Year Total |
|---|---|---|
| Securing broodstocks | $ 25,000 | $ 200,000 |
| IHN testing | 40,000 | 320,000 |
| Monitoring success of project | 35,000 | 280,000 |
| Gravel cleaning (if warranted) | 10,000 | 80,000 |
| Predator removal (if warranted) | 10,000 | 80,000 |
| Construction of incubation facility on Umbrella Creek | 40,000 | 40,000 |
| TOTAL COSTS . . . . . . . . . . | $160,000 | $1,000,000 |

Benefits:

Harvestable sockeye at 15,000 fish/year

| | | |
|---|---|---|
| Commercial harvest | 12,000 fish* | $150,000 |
| Sport harvest | 3,000 fish* | $150,000 |

*To be finalized by harvest managers, but we believe this split to be realistic based upon remoteness of Ozette.

20-Year Benefit1//Cost2/ Ratio: $3.6 million/1.58 million - 2.3

1/ Assumes no harvest for initial 8 years.

2/ Includes ongoing monitoring for WDF and Makah for 20 years.

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Appendix

# LAKE OZETTE SHORELINE AND TRIBUTARY SPAWNING GROUND SURVEYS

## 1977 - 1980

| Stream | Date | Method | River Mile Section | Species | Live | Dead |
|---|---|---|---|---|---|---|
| Big River | 12-01-79 | Foot | 7.2 - 9.5 | Coho | 38 | 0 |
| | 12-18-79 | Foot | 7.2 - 9.5 | Coho | 24 | 4 |
| | 01-06-80 | Foot | 7.2 - 9.5 | Coho | 8 | 7 |
| Solberg Creek | 10-10-79 | Foot | 0.0 - 1.0 | | 0 | 0 |
| | 10-30-79 | Spot | 0.0 - 0.4 | Coho | 2 | 0 |
| | 11-06-79 | Foot | 0.0 - 1.0 | Coho | 6 | 0 |
| | 11-30-79 | Foot | 0.0 - 1.0 | Coho | 10 | 1 |
| | 12-17-79 | Foot | 0.0 - 1.0 | Coho | 4 | 0 |
| Trout Creek | 10-20-79 | Foot | 0.0 - 3.5 | | 0 | 0 |
| | 11-18-79 | Foot | 0.0 - 1.0 | Coho | 5 | 0 |
| Crooked Creek | 10-30-77 | Foot | 0.0 - 1.5 | | 0 | 0 |
| | 11-24-78 | Foot | 0.0 - 1.4 | Coho | 3 | 0 |
| | | | | Kokanee | 140 | 8 |
| Quinn Creek | 11-16-77 | Foot | 0.0 - 0.5 | Kokanee | 20 | 0 |
| | 12-20-78 | Foot | 0.0 - 0.5 | | 0 | 0 |
| Elk Creek | 12-01-77 | Foot | 0.0 - 0.6 | Kokanee | 246 | 0 |
| | 11-28-78 | Foot | 0.0 - 0.4 | Kokanee | 60 | 0 |
| | 12-06-79 | Foot | 0.0 - 0.4 | Kokanee | 80 | 3 |
| Siwash Creek | 11-28-78 | Foot | 0.0 - 1.0 | Kokanee | 220 | 0 |
| | 12-06-79 | Foot | 0.0 - 1.0 | Kokanee | 116 | 0 |
| Lost Net Creek | 11-30-78 | Foot | 0.0 - 0.4 | Kokanee | 84 | 0 |
| | 12-08-79 | Foot | 0.0 - 0.4 | Kokanee | 46 | 0 |
| South Creek | 12-02-74 | Foot | 0.0 - 1.0 | | 0 | 0 |
| | 11-20-77 | Foot | 0.0 - 1.0 | | 0 | 0 |
| | 10-24-78 | Foot | 0.0 - 1.0 | Coho | 4 | 0 |
| | 11-28-78 | Foot | 0.0 - 1.0 | Kokanee | 140 | 0 |
| Coak Creek | 12-01-77 | Foot | 2.2 - 3.0 | | 0 | 0 |
| | 11-04-78 | Foot | 0.2 - 1.0 | Coho | 6 | 0 |
| | 11-20-78 | Foot | 0.2 - 1.0 | Coho | 3 | 1 |
| Umbrella Creek (N.E. Branch) | 11-22-77 | Foot | 0.0 - 1.4 | Coho | 6 | 0 |
| Umbrella Creek | 11-22-77 | Spot | 0.9 | Coho | 2 | 0 |
| | 10-17-78 | Foot | 3.5 - 4.6 | | 0 | 0 |
| | 10-24-78 | Foot | 6.0 - 7.2 | | 0 | 0 |
| E. Branch Umbrella Cr. | 10-30-78 | Foot | 0.0 - 1.0 | | 0 | 0 |
| Umbrella Creek | 11-28-78 | Foot | 0.0 - 0.9 | Coho | 4 | 0 |
| | 11-28-78 | Foot | 0.9 - 3.5 | Coho | 5 | 0 |
| | 11-28-78 | Foot | 3.5 - 4.6 | Coho | 8 | 0 |
| | 11-28-78 | Foot | 4.6 - 7.0 | Coho | 3 | 0 |
| W. Branch Umbrella Cr. | 11-28-78 | Foot | 0.0 - 1.4 | | 0 | 0 |
| Umbrella Cr. | 01-01-79 | Foot | 0.9 - 3.5 | Coho | 0 | 1 |
| N.E. Branch Umbrella Cr. | 01-04-79 | Foot | 0.0 - 1.4 | Coho | 0 | 1 |
| Ozette River | 10-20-77 | Boat | 0.0 - 4.6 | Coho | 10 | 0 |
| | 11-16-78 | Boat | 3.0 - 4.6 | Coho | 20 | 3 |
| | 11-19-79 | Boat | 0.0 - 4.6 | Coho | 12 | 4 |
| Lakeshore Surveys | | | | | | |
| East Shore | 11-22-78 | Boat | | Sockeye | 10 | 0 |
| | 12-06-78 | Boat | | Sockeye | 34 | 0 |
| | 12-20-78 | Boat | | Sockeye | 60 | 4 |
| | 01-08-79 | Boat | | Sockeye | 16 | 12 |
| | 01-22-79 | Boat | | Sockeye | 6 | 4 |

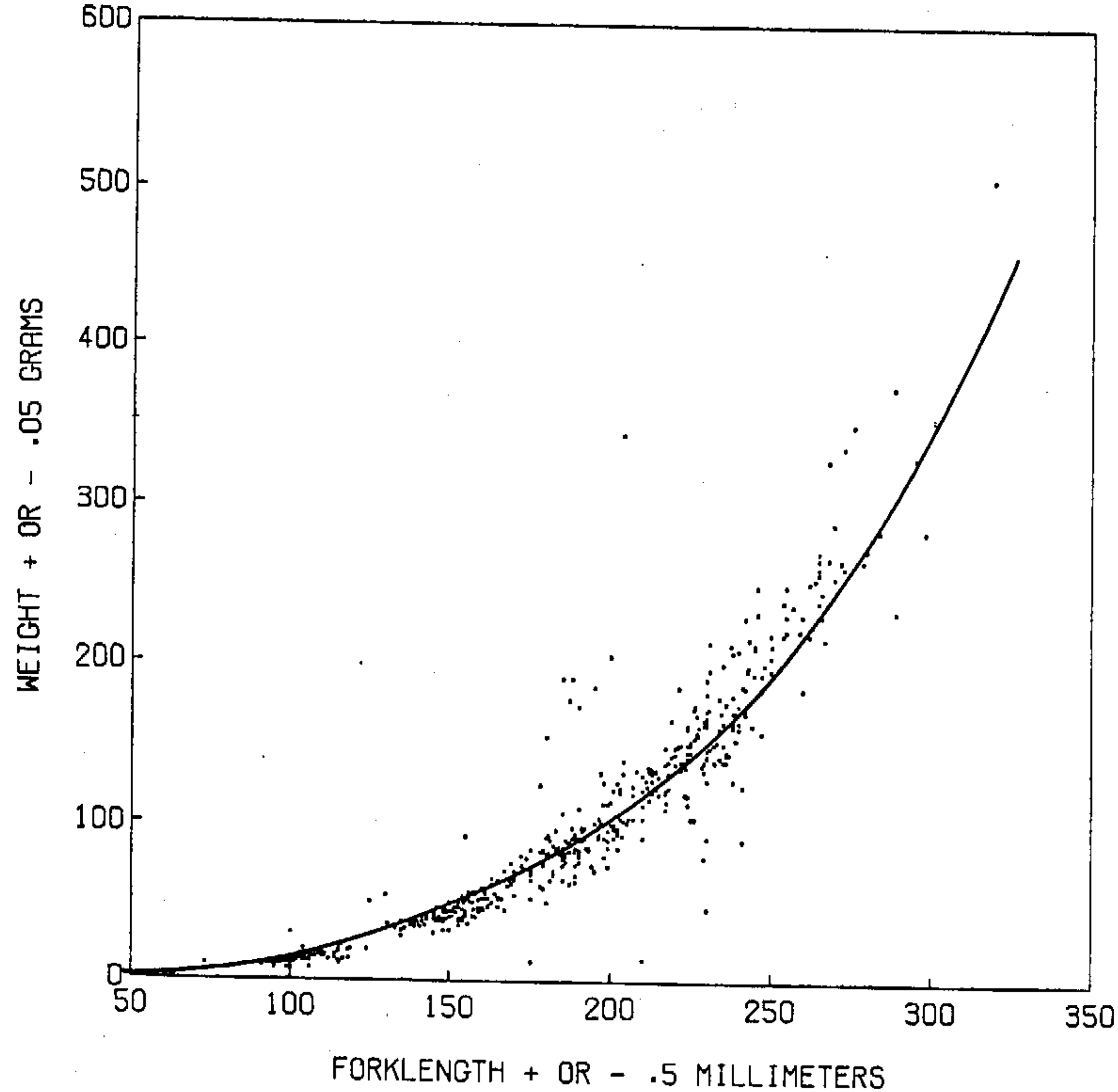
LAKE OZETTE SHORELINE AND TRIBUTARY SPAWNING GROUND SURVEYS

1977 - 1980

| Stream | Date | Method | River Mile Section | Species | Live | Dead |
|---|---|---|---|---|---|---|
| West Shore | 12-06-78 | Boat | | | 0 | 0 |
| | 12-20-78 | Boat | | Sockeye | 10 | 0 |
| | 01-02-79 | Boat | | Sockeye | 46 | 0 |
| | 01-14-79 | Boat | | Sockeye | 150 | 0 |
| | 01-26-79 | Boat | | Sockeye | 64 | 6 |
| | 02-04-79 | Boat | | Sockeye | 40 | 12 |
| | 02-23-79 | Boat | | Sockeye | 20 | 5 |
| North Arm | 01-20-79 | Boat | | Sockeye | 30 | 0 |
| | 02-08-79 | Boat | | Sockeye | 10 | 0 |
| | 03-01-79 | Boat | | Sockeye | 2 | 0 |

# Appendix 2

## Length - Weight Regressions And Mean Calculated Fork Lengths At Each Annalus For Various Lake Ozette Fish.

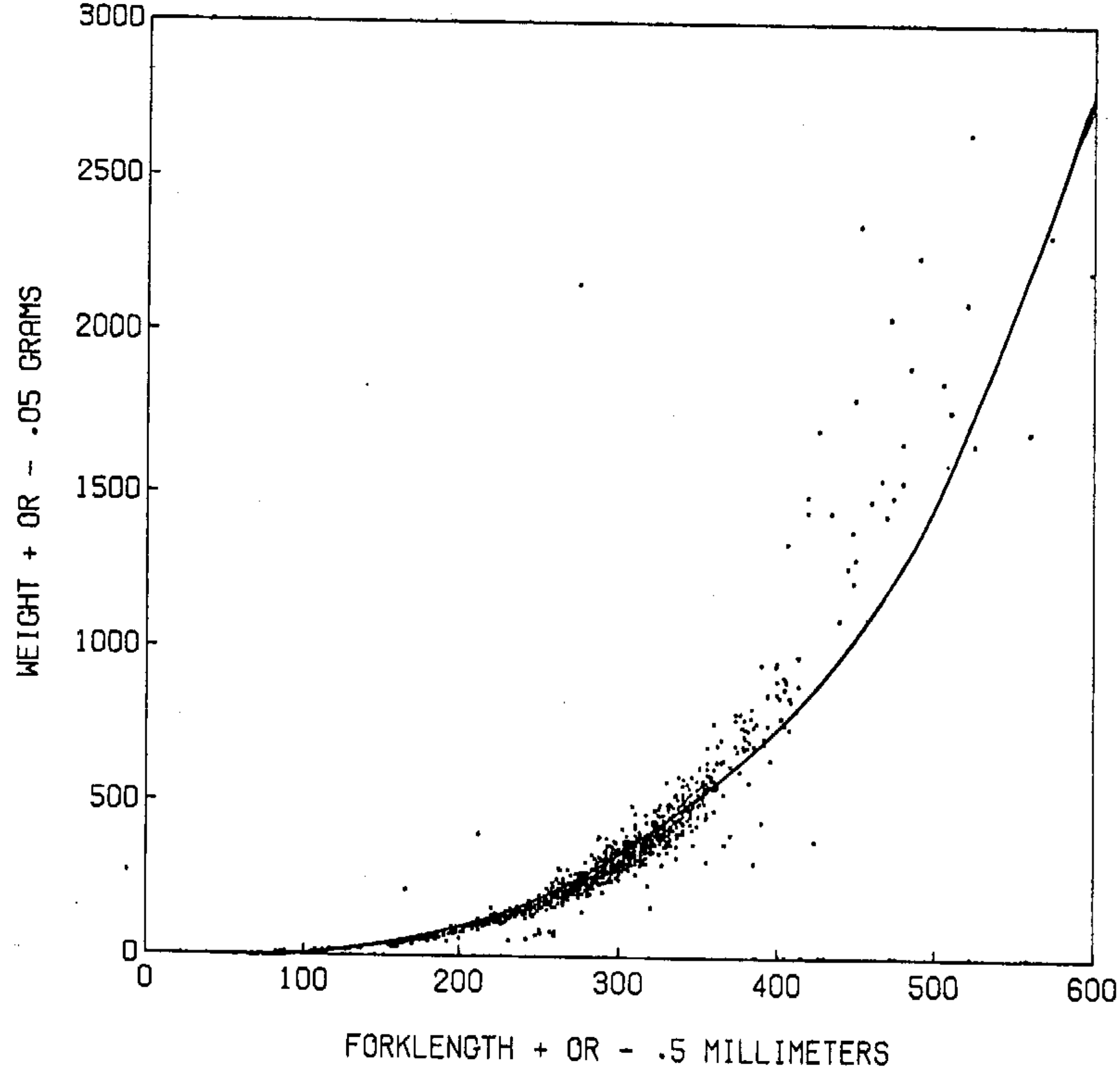



LENFORK VERSUS WT 549 VALUES

1977-79 LAKE OZETTE YELLOW PERCH LENGTH WEIGHT REGRESSION

Mean calculated fork length at each annulus for 369 Lake Ozette yellow perch, sexes combined.

| Age Group | Mean FL (mm) | Mean Total Scale Radius (mm) | Mean Fork Length at Annulus (mm) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1+ | 106 | 30 | 67 | | | | | | | | |
| 2+ | 153 | 50 | 68 | 119 | | | | | | | |
| 3+ | 186 | 63 | 69 | 116 | 166 | | | | | | |
| 4+ | 215 | 75 | 72 | 121 | 167 | 203 | | | | | |
| 5+ | 224 | 80 | 72 | 118 | 162 | 192 | 213 | | | | |
| 6+ | 247 | 91 | 74 | 124 | 167 | 200 | 224 | 240 | | | |
| 7+ | 246 | 94 | 73 | 119 | 157 | 191 | 213 | 229 | 242 | | |
| 8+ | 288 | 114 | 64 | 114 | 161 | 209 | 244 | 261 | 276 | 284 | |
| 9+ | 289 | 86 | 93 | 133 | 168 | 205 | 226 | 252 | 266 | 275 | 280 |
| Totals (Mean) | 217 | 76 | 72 | 121 | 164 | 200 | 224 | 246 | 261 | 280 | 280 |
| Totals (Mean) 1+ - 6+ | 189 | 65 | 70 | 120 | 166 | 198 | 219 | 240 | | | |

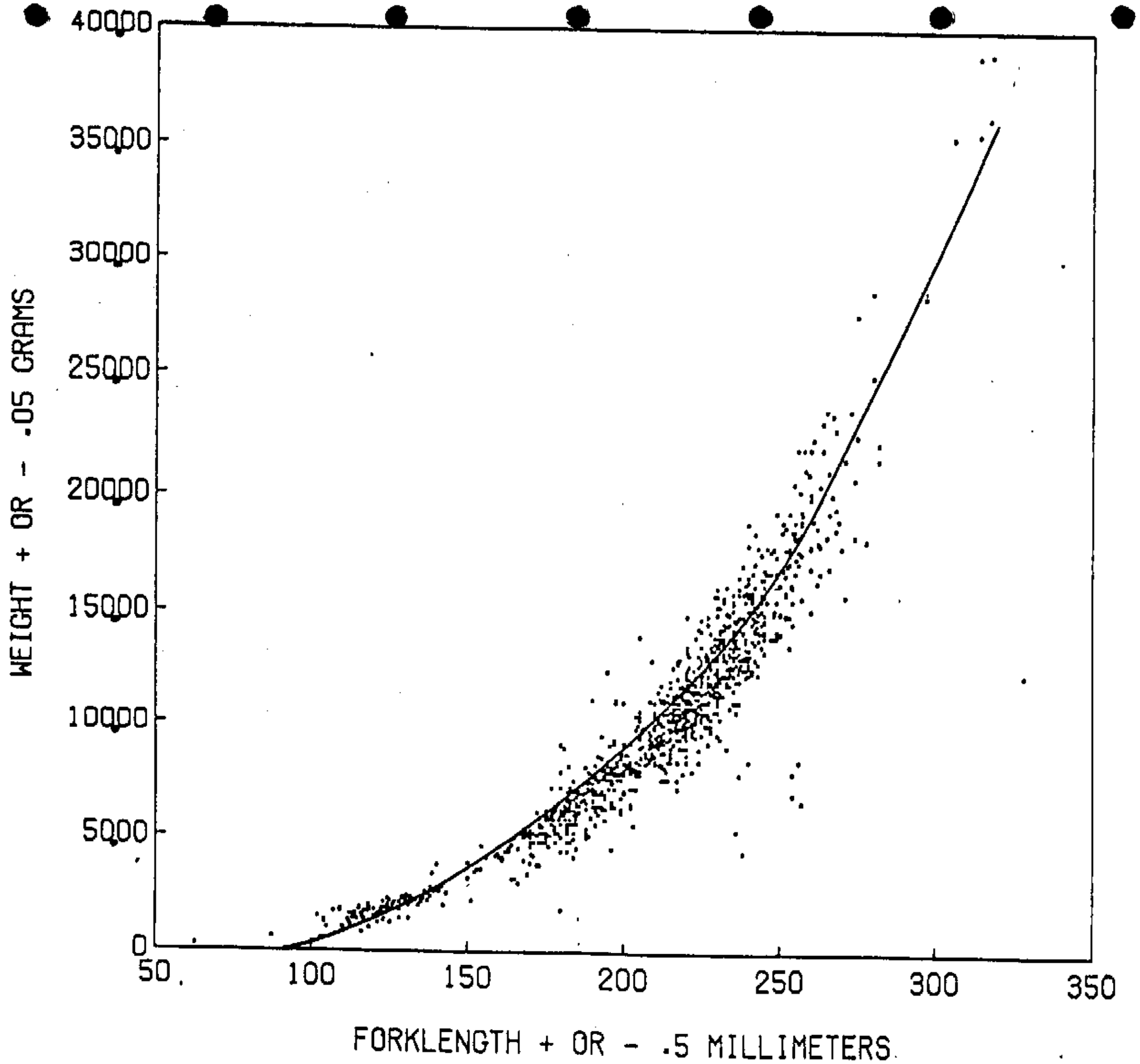



LENFORK VERSUS WT 1081 VALUES

1977-79 LAKE OZETTE SQUAW FISH LENGTH WEIGHT REGRESSION

Mean calculated fork length at each annulus for 194 Lake Ozette squawfish, sexes combined.

| Age Group | Number | Mean Calculated Fork Length at Each Annulus (mm) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | |
| 2 | 1 | 38 | 71 | | | | | | | | | | | | | |
| 3 | 7 | 31 | 69 | 113 | | | | | | | | | | | | |
| 4 | 18 | 35 | 79 | 91 | 162 | | | | | | | | | | | |
| 5 | 20 | 34 | 74 | 118 | 161 | 201 | | | | | | | | | | |
| 6 | 30 | 35 | 78 | 123 | 160 | 198 | 233 | | | | | | | | | |
| 7 | 35 | 38 | 97 | 121 | 156 | 193 | 227 | 255 | | | | | | | | |
| 8 | 32 | 37 | 80 | 122 | 163 | 200 | 233 | 263 | 289 | | | | | | | |
| 9 | 25 | 28 | 79 | 118 | 156 | 191 | 225 | 258 | 285 | 310 | | | | | | |
| 10 | 14 | 35 | 86 | 132 | 174 | 210 | 244 | 270 | 296 | 320 | 343 | | | | | |
| 11 | 3 | 33 | 68 | 103 | 140 | 187 | 220 | 247 | 284 | 307 | 328 | 350 | | | | |
| 12 | 4 | 43 | 80 | 116 | 151 | 176 | 202 | 224 | 257 | 278 | 305 | 325 | 337 | | | |
| 13 | 1 | 27 | 63 | 96 | 135 | 156 | 176 | 205 | 233 | 257 | 277 | 308 | 324 | 365 | | |
| 14 | 2 | 30 | 74 | 115 | 149 | 180 | 219 | 257 | 297 | 329 | 361 | 379 | 404 | 454 | 489 | |
| 15 | 2 | 40 | 78 | 119 | 155 | 191 | 235 | 273 | 309 | 330 | 379 | 409 | 438 | 471 | 504 | 532 |
| Mean | | 35 | 77 | 114 | 155 | 189 | 221 | 250 | 281 | 304 | 332 | 354 | 376 | 430 | 497 | 532 |
| Increments | | 35 | 42 | 37 | 41 | 34 | 32 | 29 | 31 | 23 | 28 | 22 | 22 | 54 | 67 | 35 |

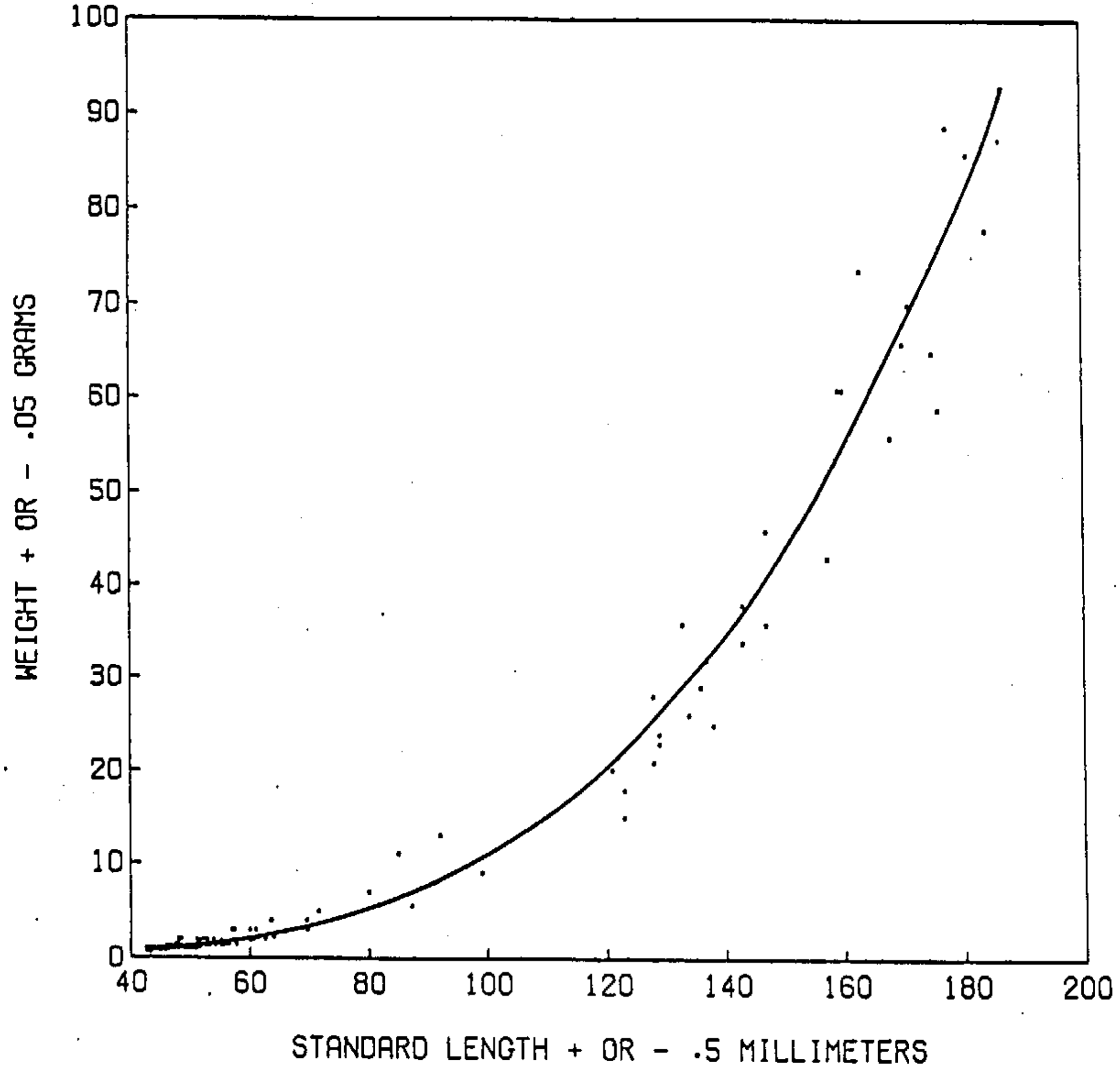



LENFORK VERSUS WT · 1199 VALUES

1977-79 LAKE OZETTE PEA MOUTH LENGTH WEIGHT REGRESSION

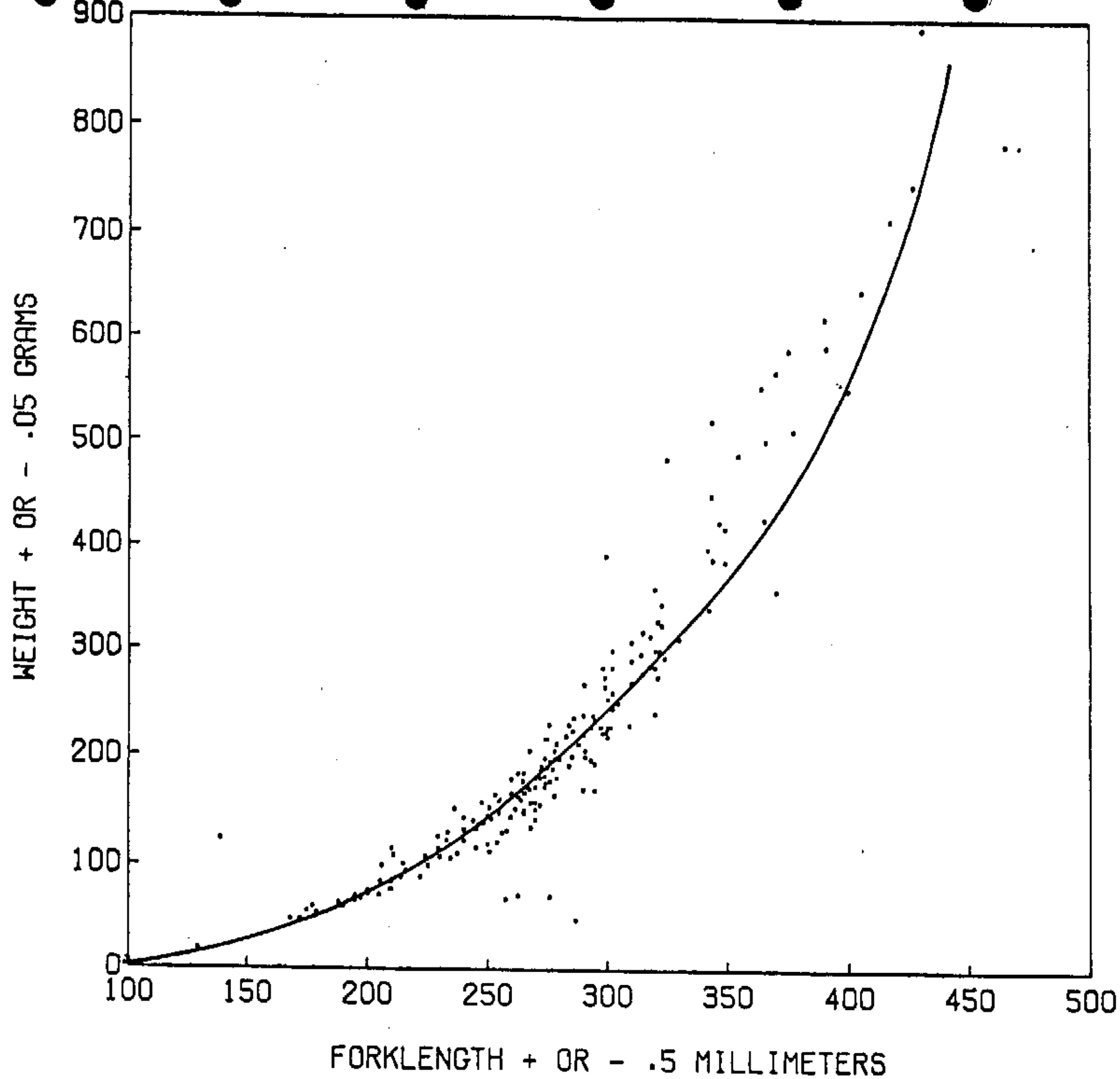
Mean calculated fork length at each annulus for 82 Lake Ozette peamouth, sexes combined.

| Age Group | Number | Mean Fork Length at Capture (mm) | Calculated Fork Length at Each Annulus (mm) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| II | 1 | 120 | 31 | 92 | | | | | | |
| III | 3 | 133 | 42 | 89 | 120 | | | | | |
| IV | 8 | 176 | 36 | 77 | 123 | 168 | | | | |
| V | 20 | 192 | 35 | 77 | 117 | 157 | 186 | | | |
| VI | 31 | 221 | 36 | 75 | 120 | 158 | 192 | 219 | | |
| VII | 18 | 233 | 38 | 77 | 119 | 156 | 191 | 219 | 244 | |
| VIII | 1 | 268 | 40 | 84 | 133 | 164 | 205 | 240 | 264 | 307 |
| Weighted Averages: | | | 36 | 77 | 119 | 158 | 190 | 219 | 245 | 307 |
| Increments of Growth: | | | 36 | 41 | 42 | 39 | 32 | 29 | 26 | 62 |
| Number of Fish | | | 82 | 82 | 81 | 78 | 70 | 50 | 19 | 1 |
| Estimate of Standard Deviation: | | | 1.38 | 2.14 | 2.56 | 2.32 | 2.37 | 2.54 | 3.05 | 0 |



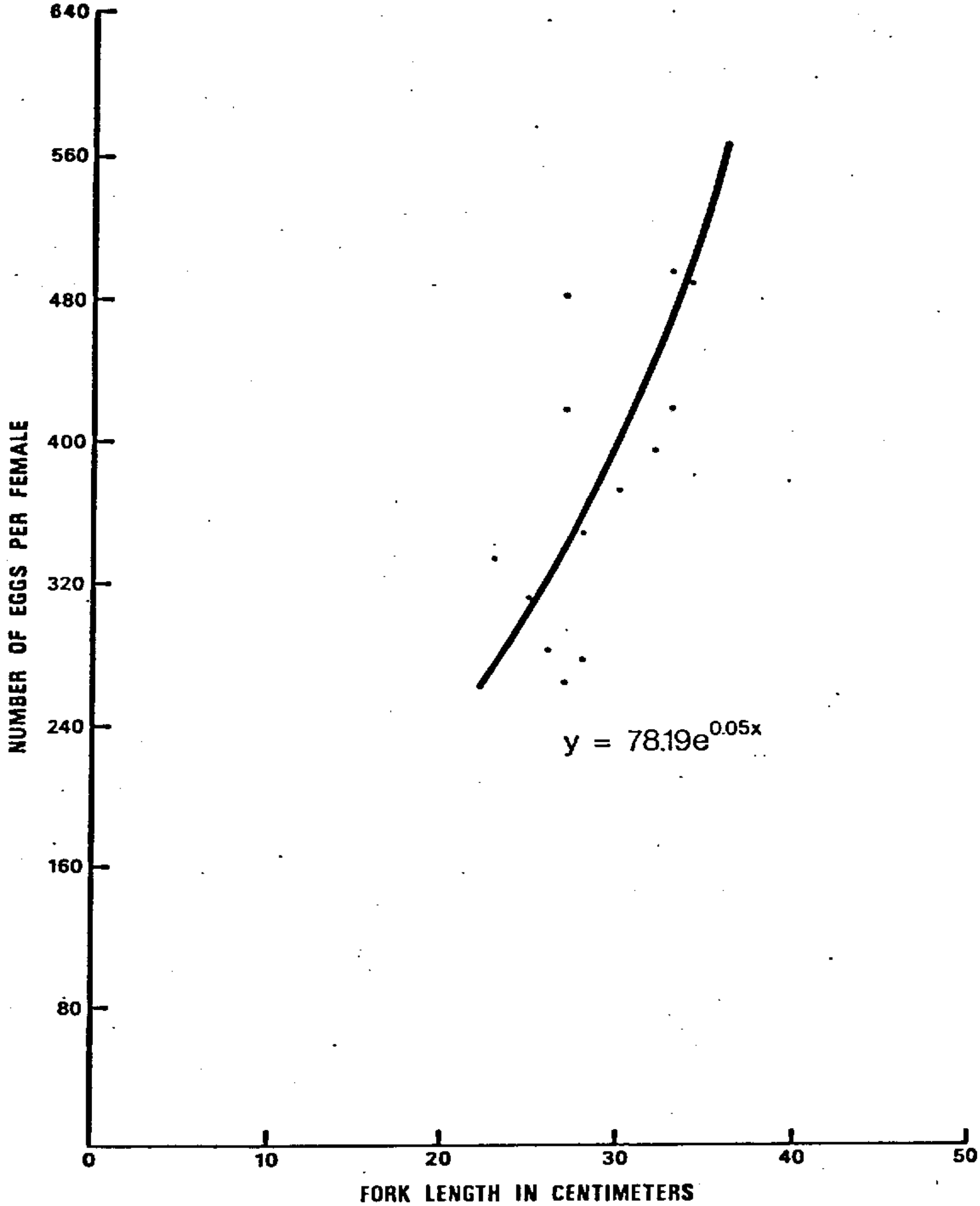

LENFORK VERSUS WT 129 VALUES

1977-79 LAKE OZETTE PRICKLY SCULPIN LENGTH WEIGHT REGRESSION




LENFORK VERSUS WT 194 VALUES

1977-79 LAKE OZETTE CUT THROAT TROUT LENGTH WEIGHT REGRESSION




Observed and calculated fecundity as a function of fork length for cutthroat trout from Lake Ozette, 1978–79.